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THE OPTICS OF CURVED GLASS

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Abstract

Glass is characterized by its capacity to transmit vision. In many applications glass elements produce desirable changes in the brightness or apparent dimensions of the image transmitted, while windows characteristically produce a minimum of change. In the case of optical instruments, the dependence of transmission and optics on the glass composition and optical design is well known. A window is also an optical element and its performance depends on its design. The key to this dependence is Snell's law: $n_i \sin i = n_r \sin r$. Using this relationship, simplified equations can be developed for the deviation of light rays through windows.

Simplified equations have been published which show the effect of wedge in certain flat optical elements. The present paper includes equations for the deviations due to thickness, wedge and curvature in windows. The results are shown graphically. An example is given in which seriously deficient performance was overcome by proper design of a curved glass window. It is thus shown that optical performance is a consequence of the glass shape, so that optics as well as other architectural features should be considered in the design of curved glass windows.

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The word "glass" suggests transparency. In the great majority of applications glass is used because of its capacity to transmit a visual image. However, the images transmitted may be somewhat changed, and in many cases these changes are quite desirable.

For example, sun glasses are ordinarily intended to appreciably reduce the quantity of light without changing the image dimensions. Binoculars, however, must change the image size in order to be useful, while the loss of light should be held to a minimum. Transparent windows characteristically produce a minimum of change in both the brightness and the dimensional appearance. In general, these image characteristics are a result of the transmisison of optics or the optical elements.

In the case of optical instruments, we are aware of this dependence of the functional qualities on the glass composition and optical design. Because of the variety and complexity of the optical systems used, both transmission and optics continue to be important problems in instrument design, and receive a great deal of attention.

On the other hand, the satisfactory performance of glass windows, which have been predominantly flat, has fostered little interest in the question of design. The excellent transparency of these windows result from the use of relatively thin layers of glass having low absorption. In fact, the losses due to absorption are normally much less than the losses due to surface reflection. With regard to the high quality of vision, our glass manufacturers deserve considerable credit for improving flat glass up to its present state, but it should also be brought out that flatness in window design does not limit the optical performance.

Although, from an optical point of view, the purpose of a window is to "do nothing", this ideal performance can be approached only as a result of an appropriate design. Likewise, a radically different design may result in an objectionably different optical performance. In other words, a window is an optical element and, like other optical elements, its performance depends on its design.

This dependence of optical performance on glass design is a result of the capacity of the glass surfaces to bend the transmitted light rays. The amount of bending at a transparent surface depends on the angle of incidence and on the property of the glass known as the index of refraction. This relationship is known as Snell's law.

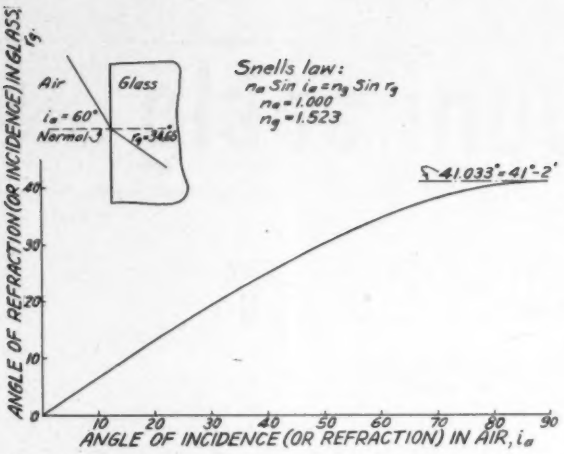

Fig. 1. Refraction according to Snell's Law.

Fig. 1 is a graphical representation of Snell's law, and hence shows the relationship between the angles of incidence and refraction at a glass surface. The angle in air, whether the light is approaching or leaving the surface, is read along the horizontal axis, while the angle in glass is read along the vertical. By using this relationship at both surfaces of each optical element, the path of any ray can be followed through even complex optical systems. In the case of windows, simplified approximate relations can be developed from Snell's law for the deviation due to thickness, non-parallelism and curvature. It should be mentioned that simplified equations have also been developed by others for showing optical effects of non-parallelism in elements with plane surfaces.[1]

Fig. 2 shows the effect of *thickness*. The displacement is plotted as a function of the angle of incidence for flat, parallel surfaced glass. It will be noted that this effect increases with the angle of incidence and equals the thickness of the glass at an angle of 90°. Since the effect consists of a lateral displacement, it is usually of little importance when the object is at any appreciable distance from the window.

[1] H. M. Reese, "Multiple Images in Car Windows." J. Opt. Soc. Am. 21, 282 (1931); Morton Masius and W. E. Lawton, "On the Refraction of a Liquid Between Two Thin Prisms." J. Opt. Soc. Am. 20, 271 (1930); Paul W. Stevens, "Analysis of Errors in a Reflecting Prism." J. Opt. Soc. Am. 33, 74 (1943).

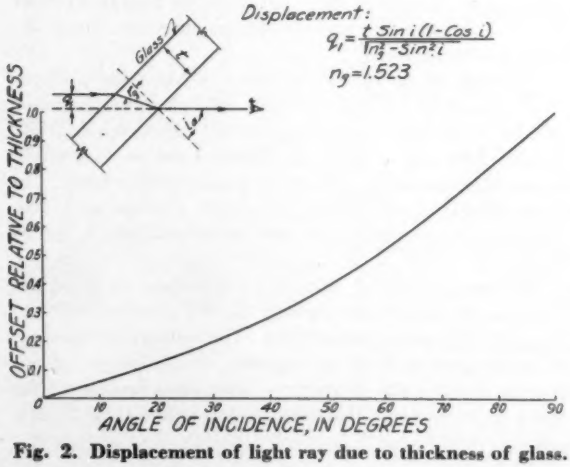
Displacement:
$q_1 = \frac{t \sin i (1 - \cos i)}{\sqrt{n_g^2 - \sin^2 i}}$
$n_g = 1.523$
Glass
OFFSET RELATIVE TO THICKNESS
ANGLE OF INCIDENCE, IN DEGREES

Fig. 2. Displacement of light ray due to thickness of glass.

As illustrated in the figure, the light ray is bent into the glass. The lateral displacement of the approaching light ray is thus downward in the figure, and the apparent displacement of the image is in this same direction. However, since the value of this displacement is usually negligible, it is seldom necessary to consider its direction.

The equation from which the curve was drawn is also shown; this equation is exact and hence accurate for all significant value of i and t.

Fig. 3 gives the effect due to *non-parallelism* as a function of the angle of incidence. As shown in the figure the deviation is just over ½ of the wedge angle at normal incidence, but at 60° it is about 1½ times as large as the wedge angle. It will be seen that this effect is angular, increases rapidly at oblique angles of incidence, and is independent of the thickness.

The diagram in Fig. 3 shows that the light ray is bent in the direction of increasing thickness. In more familiar terms, the deviation is toward the base of the prism. However, it will be seen that the apparent displacement of the image is in the opposite direction, that is, in the direction of thinner glass.

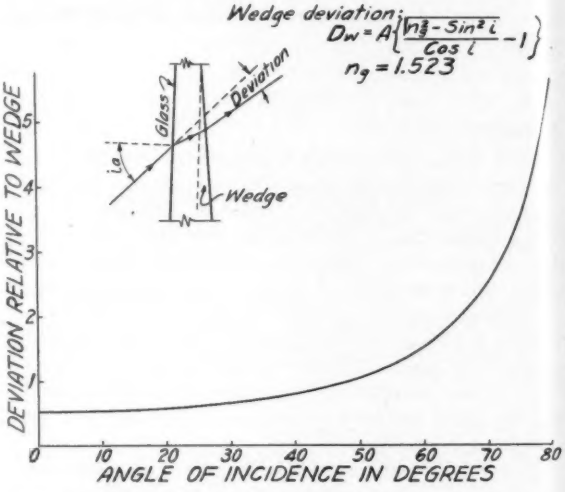

Fig. 3. Light deviation due to wedge in glass.

The equation given with the curve of Fig. 3 is an approximate form. It will be seen that this form is much more convenient than the application of Snell's law at both surfaces. Moreover, there is little loss in accuracy for small values of wedge and angle of incidence. The following table compares the deviation as calculated by the approximate and exact methods, for glass with a wedge angle of 5.74 minutes (Specification AN-DDG-551).

Deviation Calculations, for glass with 5.74 minutes of wedge

Angle of incidence	0°	30°	60°
Deviation, exact (7 place logs)	3.002 min.	3.786 min.	8.589 min.
Deviation, approximate	3.002 min.	3.791 min.	8.632 min.
Difference	0.00%	+0.13%	+0.50%

Fig. 4 shows the effect of *curvature and thickness* as a function of the angle of incidence. This curvature effect may be considered as a kind of wedge effect resulting from the fact that the tangent planes at the point of entrance and emergence are not parallel. It will be seen that this curvature wedge between the surfaces for a given ray depends on both the thickness and the curvature. The deviation is given in minutes by multiplying the value of the factor f(i) by the ratio of the thickness to the radius of curvature. For glass which is ½ inch in thickness with a radius of curvature of 50 inches, the deviation, in minutes, will be 1/100 of the f values shown in Fig. 4. Thus, for ∠ i = 30° the deviation would be just under 8 minutes, and for 60° it would be about 36 minutes. If both the radius of curvature and the thickness are increased proportionately, the deviation remains constant. The deviation increases markedly at oblique angles of incidence.

The illustration in Fig. 4 shows that the light ray is bent away from the center of curvature. Here again, the apparent image displacement is in the opposite direction to the deviation, or toward the center of curvature. In many cases the curvature effect is so predominant that the deviation due to wedge as well as the thickness offset may be neglected.

The equation for deviation due to curvature and thick-

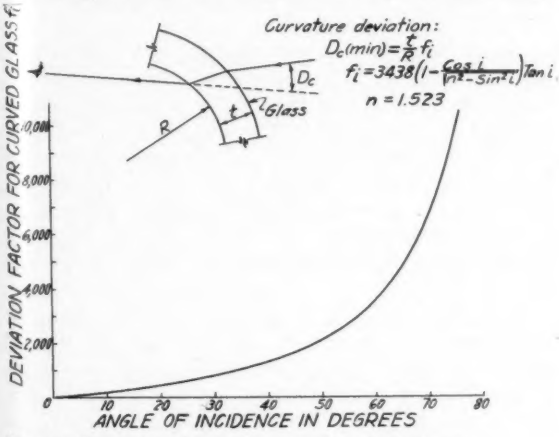

Fig. 4. Deviation due to curvature and thickness.

ness shown in Fig. 4 is an approximation. Like the equation for deviation due to wedge, this equation is convenient and at the same time quite accurate for small values of thickness per radius ratio and angle of incidence. The following table gives calculations for deviation by the approximate and exact methods for ⅜-inch glass having a radius of curvature of 15 inches.

Deviation Calculations for ⅜-inch Glass Bent to a 15-inch Radius

Angle of incidence	0°	30°	60°
Deviation, exact (7 place logs)	0.000	19.607	84.64
Deviation, approximate	0.000	19.750	89.46
Difference	0.00%	+0.73%	+5.69%

Fig. 5 gives a *comparison* of these effects to illustrate

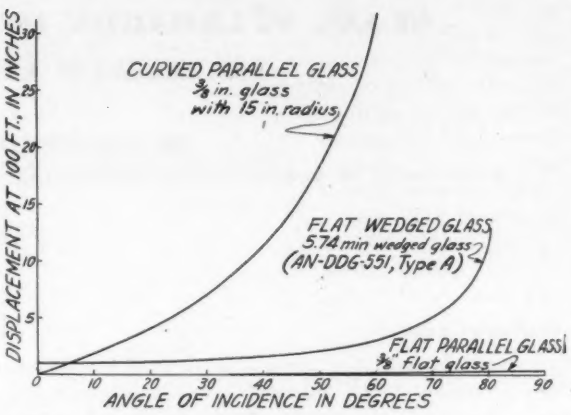

Fig. 5. Comparative displacement effects for glass with n = 1.523.

their relative importance. The curves in this figure give the apparent displacement at 100 feet due to specific dimensional properties. Here it will be seen that the displacement due to a thickness of ⅜ inch in flat parallel glass is quite insignificant in comparison with the other effects shown. The displacement at 100 feet due to flat glass with 5.74 minutes of wedge is between 1 and 3 inches for angles of incidence between 0 and 60°. The displacement for ⅜ inch glass curved to a 15 inch radius varies between 0 and 30 inches for the same range of incidence angles. To keep the displacement under 3 inches for the curved glass, the angle of incidence must not exceed about 15°. While the deviation for the curved glass illustrated in the figure is relatively severe except near normal incidence, it is interesting to note that ¼ inch glass curved to a 50 inch radius would cause only 20% as much deviation under the same conditions.

In general, more than one of these dimensional effects will occur at the same time, so that the net deviation is a composite effect. In case the separate deviations are in the same direction or in opposing directions, the net value can be obtained by simply adding or subtracting the separate deviation values.

An interesting application in which objectionable curvature effects were overcome was the development of sighting panels for airplane gun turrets. It was found that a certain panel produced a deviation of the line of sight which varied from 0 to 48 minutes; this cor-

(*Continued on page 576*)

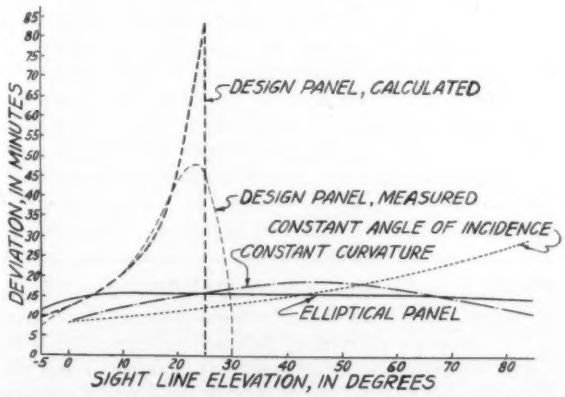

Fig. 6. Deviation for sighting panel and various modifications.

GLASS STANDARDS OF WEIGHT AND VOLUME IN EIGHTH CENTURY EGYPT

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PART II

Chemical Analyses

When the sixteen Arabic glass weights and stamps had been examined for Workmanship and weathering and their indices of refraction and apparent specific gravities had been determined, it was evident that No. 196, the vessel stamp which could be destroyed for analysis because its inscription was illegible, was not representative of the major portion of the group. One of the ten pieces in Group A that were alike in index and probably in specific gravity would better illustrate the glass composition in the collection studied. Fortunately, one of the large ring weights, No. 34, of Group A had excess glass on a broken portion of the ring from which a sample could be removed without endangering the inscription or spoiling the piece for exhibit purposes. A two-gram sample was therefore cut out with a diamond saw.

Since the physical properties of Nos. 34 and 196 were considerably different, it seemed of interest to determine the chemical basis of this variation. Miss Mildred C. Parrish, of the Glass Section of the Research Laboratories of the Armstrong Cork Company, Lancaster, Pennsylvania, analyzed the two glasses reported in Table II.

TABLE II
Chemical Analyses of Two Arabic Glasses

	No. 34	No. 196
SiO_2	71.40	68.86
FeO	0.82	0.36
Fe_2O_3	1.11	0.61
(Total iron as Fe_2O_3)	(2.02)	(1.01)
Al_2O_3	4.75	1.63
CaO	2.74	10.02
MgO	0.81	1.57
Na_2O	16.98	15.88
K_2O	0.27	0.05
MnO	0.30	0.19
CuO	0.10	0.00
SO_3	0.12	0.19
Loss on ignition	0.28	0.21
SnO	0.00	0.00
PbO	0.00	0.00
	99.68	99.57

I wish to acknowledge with much appreciation her aid in this study. Her methods were those she employs daily in the chemical analysis of modern commercial glasses.

The immediate tendency when one obtains an analysis of an ancient glass is to compare it with those already published. Before turning to this confusing pleasure, there is much that can be observed from the present analyses alone.

The two glasses analyzed are of the soda-lime-silica type. No. 196 is quite similar to modern container glass compositions although a little low in SiO_2 and very high in Fe_2O_3. This is the glass that weathered and was not typical of most of the pieces examined. Although emphasis is placed on the weathering in this discussion because so few of the glasses exhibited it, the fact that it has withstood attack as well as it has can be attributed to its moderate R_2O_3 (2.6%) and alkali (17.45%) content, which tended to counteract each other with respect to weathering.

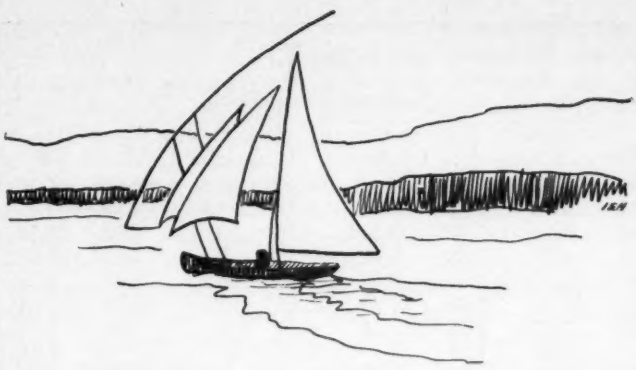
No. 34 has an unusual composition, very high in R_2O_3 and very low in CaO. Perhaps the closest analogy in modern commercial glasses would be to lime bulb glasses although they are lower in R_2O_3 and higher in CaO than No. 34. The very high R_2O_3 (6.8%) content explains why the glass surfaces show no weathering. It also indicates that the glass was doubtless quite viscous at the operating temperatures. The appearance of the larger pieces, full of seeds, cords and a few stones, would bear this out.

It would be possible to go into a detailed discussion of properties of the glasses, such as viscosity, thermal expansion, surface tension and density, that can be approximated from oxide factors, but this would be misleading for it is not likely that the Arabic glass was made under ideal conditions where such working properties might be of importance. Experienced glassmakers had fashioned vessels for over a thousand years before these weights and stamps were made, but their traditions and skills would have only indirect application in the routine manufacture of products in the Bureau of Standards (Cairo).

The glass batch was probably melted in clay crucibles in small updraft kilns such as those used to fire pottery. When the pots were removed from the kiln, there were glassy zones and also unmelted batch remaining in the crucibles. The reasonably clear glass would be picked out when the crucible was broken open. Then, when glass objects were to be formed, chunks of this glass would either be remelted or softened in the equivalent of a glory hole.* In a process such as that just outlined, exactly reproducible glasses would be rare, but approximate compositions could be maintained in a glass shop. It is possible to calculate the batch composition from the chemical analyses if certain assumptions are made about the raw materials used, but the two-stage process of glass preparation would so alter the proportions in the final

* There are indications in ancient texts that such a procedure was followed because many of the formulas call for the use of one or more special glasses in compounding a batch.

glass that the results of such calculations might have little relation to the actual proportions used. For example, it would be rather difficult to prepare a clear glass containing almost 5% Al_2O_3 such as occurs in No. 34 if the alumina were introduced as clay, but with remelting this composition could be attained. It is of course possible that feldspar was used in the batches to introduce the alumina, but it is not too likely.



Glass batches were calculated and weighed out on the basis of the analyses given in Table 2. They were fired in an electric furnace to 2000° F., at which temperature they were held for two hours. When the crucibles were removed from the furnace at the end of the holding period it was found that there was much unmelted batch at the surface, but there was some molten glass in the bottom of the crucibles that could have been separated from the batch and used. No. 196 was more completely melted than No. 34, as would be expected from their Al_2O_3 contents. The glasses set up very quickly when drawn from the crucibles on an iron rod.

Similar batches were melted in a gas-fired furnace and were held at 2680° F. for one hour, after which they were poured into molds to form plates.* The batches behaved in the normal manner of container glasses as they melted. They poured readily and were quite uniform in quality and were free of stones or very coarse striae. Both glasses contained many fine seeds because no fining agents had been used. Such seeds are common in the Arabic glass, where they are often clustered at the surface or aligned in streaks.

The data from these experiments suggest that the melting temperature used was between the two limits described. As a guess, 2300° to 2500° F. was about the melting temperature. Although time is also a factor to be considered in firing schedules, it may not have been important as such in eighth century Egypt, but fuel was scarce so firings would have been of short duration. The glasses show by their imperfection that they were not kept in the furnace very long after they became molten.

Batch Materials

The nature and distribution of the materials used by the ancient Egyptians in all phases of their technology are better known than those for any other region because an able scientist, the late Mr. A. Lucas, served for many years as Chemist of the Department of Antiquities of Egypt. His book, "Ancient Egyptian Materials and Industries," is very helpful in studies such as the present one.[1]

In considering batch materials it should be kept in mind that ancient glasses were not always compounded directly from a batch. Primary glasses were frequently obtained by sorting the vitreous material from the imperfectly melted or unmelted residue. These frits or cullet then served as batch ingredients, together with additional raw materials. Assumptions as to glass batch proportions and even ingredients must therefore be made cautiously.

Sand and sandstone are plentiful in Egypt. They usually contain some iron and clay and the sands of northern Egypt also include calcite. Lucas suggests that the iron and lime in Egyptian glass were introduced as impurities in the sand. It is unlikely that this explanation can account for the total amount of each present in No. 196, but may in No. 34.

Limestone outcrops and detritus are common and could easily serve as the source of the lime in the glass. From the exceptionally small amount of CaO and MgO in No. 34 (3.55%), it can be assumed that no lime was intentionally added but that it was an impurity in the sand. In No. 196, however, lime was certainly included in the batch formula. It is probable that the low magnesian limestone used in the two Arabic glasses came from the vicinity of the glass factory. This could have been the general region of Cairo, for Lucas says, "Out of the 132 specimens of limestone from the neighborhood of Cairo analyzed by the author, all contained magnesium carbonate, but only 15 contained more than 5% and only two contained more than 20 per cent." The great difference in the CaO:MgO ratio of the two glasses, as shown in Table III, would indicate a different source of lime for the two.

Plant ashes were used as a source of alkali for glass manufacture up until recent times. Usually both Na_2O and K_2O are present, the proportions varying with the type of plant used—seaweed, wood, ferns, etc. A significant feature of the present analyses is the almost complete absence of K_2O, which indicates that plant ashes were not used to supply the alkali. Natron, a mixture of Na_2CO_3 and $NaHCO_3$, is obtained by evaporation from the waters of the Wadi Natrun, a depression in the Libyan desert about 40 miles northwest of Cairo. The material is formed into cakes and was an item of commerce in antiquity as well as today. Lucas' analyses of ancient and modern natron show that no potash is present in the salts, although in the text he mentions it as "present in very small amounts." He makes the point that when very little K_2O occurs in an Egyptian glass, it may be assumed that natron was used, "but where there is a notable amount of potash this points to the use of plant ashes or to a mixture of these with natron." It would appear that natron was the batch material used in the eighth century Arabic glasses as the source of alkali.

Clay is the most likely source of the alumina and possibly of the iron in the glass. Some of it may have been an impurity in the glass sand, and more may have come from crucible attack as the glass was melted, but there is so much present in No. 34 that it would appear that clay was an intentional batch ingredient. As has already

* These melting experiments were carried out in the Glass Section of the Research Laboratories of the Armstrong Cork Company.

TABLE III

Comparative Analyses

	No. 34	No. 196	a	b	c	d	e	f	g	h	i	j
SiO_2	71.40	68.86	67.82	67.80	68.45	67.47	70.5	66.93	65.86	68.73	67.8	69.43
Fe_2O_3	2.02	1.01	1.08	0.92	0.89	0.14	1.9	1.44	1.19	0.47	4.0	1.15
Al_2O_3	4.75	1.63	4.38	3.22	3.85	4.98	0.8	2.08	2.16	1.69		3.55
CaO	2.74	10.02	4.03	3.80	9.92	10.30	7.8	3.62	5.95	8.62	2.9	7.24
MgO	0.81	1.57	2.30	2.89	1.18	0.76	1.2	5.42	4.55	4.15	0.9	
Na_2O	16.98	15.88	13.71	16.08	14.79	15.36	16.1	15.26	12.84	12.54	23.5	17.31
K_2O	0.27	0.05	2.34	2.08	0.21	0.13	tr.	2.62	2.70	2.87		
CuO	0.10	tr.	1.96	1.51		0.31		1.76	2.66		tr.	tr.
MnO	0.30	0.19	0.91	0.44	0.75	0.51	1.1	0.28	0.88	0.74	0.9	0.39
SO_3	0.12	0.19	0.98	1.01				0.52	1.72			
SnO_2				0.51								
P_2O_5							0.6					
CaO:MgO	2.45	4.60	1.25	0.94	6.00	9.68	4.63	0.48	0.93	1.48	2.3	

a Thebes, Egypt, 1400 B.C., Dark Blue, Neumann, No. 72
b Gorub Medined, Egypt, 1500 B.C., Dark Blue inlaid with yellow and gray, Neumann, No. 95
c Alexandria, Egypt, First century B.C., Dark Blue, Neumann, No. 23
d Alexandria, Egypt, First century B.C., Dark Blue, Neumann, No. 24
e Fostat, a suburb of Cairo, Arabic period, green, Lucas, p. 422
f Samarra, Iraq, 836-895 A.D., Dark Blue Plate, Neumann, No. 83
g Samarra, Iraq, 836-895 A.D., Emerald Green window glass, Neumann, No. 84
h Cairo, 14th Century A.D., Linke in Schmoranz
i Arab Glass, Blue, Parodi quoted by Lucas, p. 420
j Pompeii, First Century A.D., Green, Neumann, No. 47

been pointed out, the large quantity of alumina in the glass could best be attained by remelting of a glass with additional batch.

The high iron content of the two glasses may be in part due to sand and clay, but it is quite possible that it was also intentionally added. An ancient Assyrian recipe for green glass, translated by Thompson,[2] calls for the addition of iron rust to the batch. It should be noted that the amount of iron present in the two glasses is roughly proportional to the alumina content. This could indicate the use of a ferruginous clay. The fluxing action of the iron as well as its ability to improve the chemical durability of a glass would make it a useful batch component when dark green colored glass is acceptable. There is relatively more FeO with respect to Fe_2O_3 in No. 196, which contains half the amount of iron of No. 34, because with increasing iron content in a glass, less of it can be maintained in a reduced state. The effect of these proportions can be seen in the color of the glasses, for the pale pieces are blue-green, while the more deeply colored glasses are yellow-green. The small amount of copper in the glass has some effect on the color.

Manganese is a common constituent of Egyptian glasses, as much as 2 per cent being present in some. The very small amount that occurs in the two Arabic glasses indicates that it is an impurity in another material or that a manganese purple glass was one of the secondary batch materials. A spot test (sodium bismuthate) showed that manganese was present in most of the green glasses and in the two blue specimens. Its use together with copper to produce a deep blue color has often misled people into assuming that cobalt was used as the colorant in Egyptian glass.

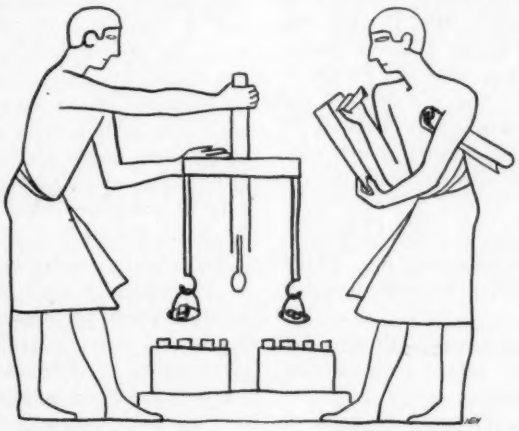
While the trace of manganese may be due to its presence as an impurity, the use of a small amount of purple glass in the batch, even when not enough to affect the color, may be of traditional or symbolic significance, for the importance of ritual in technical operations such as glass making must not be overlooked. Thompson's translation of the Assyrian directions for the preparation of a glass melting furnace supplies ample evidence.[2] A favorable day in a fortunate month must be selected, an embryo is thrown into a furnace when it is first fired, strangers and unclean people are prohibited from the area, and incense and beer are sacrificed. The Egyptians doubtless had analogous customs that might well involve a pinch of mineral ingredients or colored glass as well as beer and incense. By Arabic times the significance of the addition of manganese to the batch may have disappeared, but the tradition could still have been in force. This is sheer conjecture, but the non-material elements of a culture often influence or even dominate the material.

Only 0.1% CuO was present in No. 34 and none was found in No. 196. This was determined colorimetrically. A sensitive spot test (a-benzoinoxine) showed that a trace of copper was present in all of the green and blue glasses of the series except No. 196. Its presence certainly helped give the bluish tint to the green glasses. Copper could have been an impurity, but it is more likely that a copper blue frit such as have been found in many excavations was one of the minor batch ingredients analogous in purpose to the use of manganese. Copper blue glasses (such as the two in the present series) are common in Egypt, but no analyses of green glasses such as those in the extensive series published by Neumann[3] show the presence of very small amounts of copper. Probably spot tests and colorimetric analyses were not used. The large amount of iron in the green

glasses would mask the presence of copper in the borax bead test.

A trace of cobalt as well as copper and manganese occurred in the two deep blue glasses. A spot test using H_2O_2 and $KHCO_3$ confirmed its presence with a faintly positive reaction. It is interesting that cobalt appears in the glass in minute amounts, for there has long been much discussion, based on chemical analyses, as to whether or not cobalt was used in the production of Egyptian blue glasses. The problem was reviewed and settled spectrographically by Farnsworth and Ritchie[4] for glass of the XVIIIth Dynasty and for one fragment from the XIXth. They found that the transparent glasses of a "dark rich blue, inclining towards indigo" were colored by copper and cobalt, modified by manganese, while the "bright greenish blue, or peacock blue" was due to copper and manganese alone. The blue coin weights fall in the first group in color. Since so little cobalt is present, it is quite possible that it was an impurity in the copper ore.

Sulfur, reported as SO_3, is present in the same percentage range as in modern soda-lime glasses (0.1-0.2%). Its presence could be due to the batch materials or the fuel or both. Neumann reports sulfur contents as high as 2.4% SO_3 in the Egyptian glasses from Tell el Amarna (1400 B.C.). In such cases it is probable that gypsum was used as the source of lime or salt cake for the alkali.



Tin and lead occur in many ancient glasses, particularly those of the Arabic period, so their presence was sought in the two glasses analyzed and was not found. Lucas reported phosphorus as present in an Arab glass from Fostat. It did not occur in the glass stamps analyzed.

Comparative Analyses

Most of the published analyses of ancient glasses have been brought together in one book by Partington.[5] They all indicate that the compositions used in the past, at least of glasses that have resisted weathering and so have existed to the present time, are mostly of the soda-lime-silica type. Since the relative proportions of these three which can be successfully used in making a glass are rather limited, the range in compositions is small.

The outstanding work in the field of ancient glass analyses was done by Dr. Bernard Neumann.[3] He and his associate, Miss Kotyga, analyzed over 100 glasses of fairly well established provenience and critically evaluated the results of their work. There are a few useful analyses in the older literature, but many of the early workers did not clearly state the source and date of the samples analyzed (often they were not completely known). A statement, for example, that a piece was "Egyptian glass" is not particularly helpful. Some analysts, to judge from their published results, did not test for all of the glass components, especially those such as copper that might be present in very small amounts. Yet often it is the minor ingredients that define the character of a glass. Neumann's data are the only trustworthy large group of ancient glass compositions that can be used for comparison. Three other analyses are also of interest and will be discussed.

Analyses of glasses from Egypt and related regions were compared with the two that Miss Parrish made of the Arabic weights and stamps. Those that showed a general pattern similarity are listed in Table III together with Nos. 34 and 196. In general they contain 65-70% SiO_2, 15-18% NaKO, 4-13% CaO + MgO, and 2-5% R_2O_3. Many of the Egyptian and Roman glasses have a lower silica content (56-65%) and contain much more alkali (up to 23%). Within the group of good glasses with high silica and moderate alkali there is much variation, especially in the lime and alumina content. The pattern of what is here termed "good" glass is not limited in time or space, as the analyses show. It was made at Thebes in 1400 B.C., at Pompeii, Fostat (a suburb of Cairo), and Samarra (north of Baghdad). Roman glasses other than from Pompeii could be cited, but this survey must be limited to Egyptian and Arabic compositions with this one exception.

No 34, which is representative of most of the Arabic pieces studied, is an extreme composition in the group shown in Table III. It is the highest in SiO_2 and R_2O_3, and the lowest in CaO and MgO. It is probable that this was a special composition adapted to the manufacture of weights and stamps. A glass with low lime content would set up more slowly than one containing a normal amount; therefore, inscriptions could be stamped on the gobs of glass before they got too stiff at the fairly low operating temperatures that were apparently used. The large amount of R_2O_3 in the glass provided the necessary durability.

No. 196 is typical in composition of the series listed in Table III. It would appear that in this case glass ordinarily used for forming vessels was also used for the stamp placed on the vessel. There are several other vessel stamps in the series, however, of about the same composition as No. 34.

The CaO:MgO ratio is shown in the last line of Table III. The lack of MgO in the limestones around Cairo has already been discussed. An examination of the ratios for the several glasses will show that analyses *c*, *d*, *e* and *i* from Alexandria, Fostat and an unspecified Arab glass, all contain relatively little MgO. The other glasses approximate or exceed the dolomitic 1:1 ratio. Glass *h*, a 14th century mosque lamp from Cairo, may not have been made near that city, as gifts from many regions were brought to the mosques. Egyptian glasses *a* and *b* came from regions geologically different from that around Cairo. It would appear that the CaO:MgO ratio might serve as one means of identifying glasses as being made in the vicinity of Cairo and Alexandria.

When natron (Na_2CO_3 and $NaHCO_3$) is used as the source of alkali, there is very little K_2O in the glass.

When plant ashes are used, K_2O is present. The alkali of the two Arabic glasses analyzed was almost entirely Na_2O. The same is true of *c*, *d* and *e*, the glasses from Alexandria and Fostat. These were all made not far from where the natron was obtained, so it was probably cheaper than plant ashes. One would require a knowledge of the relative proportions of Na_2O and K_2O in many kinds of ashes before attempting to decide whether the alkali in the other glasses was due entirely to ashes or to a mixture of them with natron. Neumann's analyses show that there is appreciable K_2O in most of the XVIIIth Dynasty glasses from Tell el Amarna and Thebes, but that the majority of the pieces from the Island of Elephantine near Assuan dating from 200-100 B.C. and those from Alexandria of similar date lacked K_2O or contained only a very small amount. Lucas' analyses of four glasses from Fostat show that three of them contain K_2O. The fourth is included in Table III. Evidently both plant ashes and natron were used in many parts of Egypt for the alkali in glass batches, both tradition and economy influencing the choice.

A few comments should be made about the analyses in Table III, selected because they showed pattern similarities to the two glasses analyzed by Miss Parrish. The XVIIIth Dynasty glasses (*a* and *b*) are better in composition, Neumann pointed out, than most of the known glasses of the next 2000 years. The use of CuO and MnO to produce a dark blue glass is evident from the analyses. The SO_3 may be due to gypsum or salt cake. The SnO_2 in *b* is from a strip of decoration on the surface of the glass.

The two glasses from Alexandria made in the last few centuries B.C. are very much like those from the XVIIIth Dynasty except that they contain more lime and less alkali.

The Arabic glass *e* from Fostat is low in alumina, but its high iron content should have helped its durability. The 0.6% P_2O_5 reported looks strange.

Samarra was the capital of the Abbasid Caliphs from 836 to 892 A.D. Almost everything found at that site on the Tigris river north of Baghdad can be dated within this time interval. It is therefore of interest to compare the composition of the Arabic glass made at Samarra with that made in Cairo 50 to 100 years earlier. The examples cited in Table III were lower in silica and higher in alkali than those from Egypt. The high MgO content may be characteristic of the Iraqi glass. Neumann also analyzed three other pieces from Samarra and found that aside from containing a small amount of PbO they resembled *f* and *g*.

An early (1896) analysis of ancient glass accompanied by excellent discussion is that of Dr. F. Linke,[6] who studied a fragment of glass thought to have come from the 14th century mosque of Sultan Hasan in Cairo. The dolomitic limestone and the mixture of alkalis used in this glass would suggest that it may not have been made at Cairo, but the evidence as yet available is too meagre to to justify such a conclusion.

The series of Arab glass analyses published by Parodi[7] were republished by Lucas. Most of the glasses in this series have a high alkali content (22-31%). Example *i* is listed in Table III because of its very low lime content, in which it resembles No. 34.

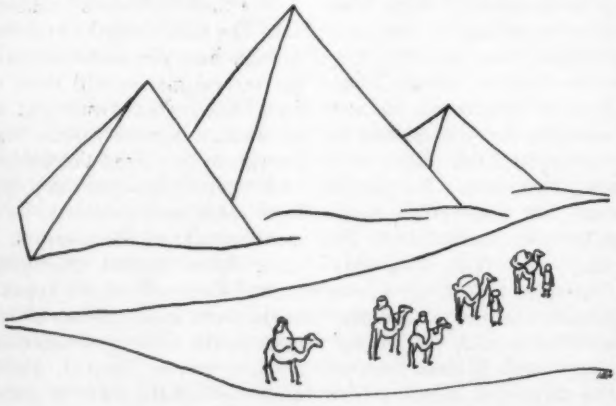
The Roman glass from Pompeii, *j*, is quite similar to the Arabic in composition. This is an excellent example of the fact that the basic formulas for easily worked yet durable glasses are very restricted in possible variation among the major ingredients.

One may not consider that the glasses cited are greatly alike in composition, yet if he were to read through the assembled analyses of ancient glasses, he would find that this group stands out as basically similar.

This survey has shown that No. 196 is similar to other Arabic and Roman glasses in composition, particularly if the source of the alkaline earths and alkalis is disregarded. However, No. 196 is unique, with one exception, among the 16 weights and stamps studied. It may have been imported to Cairo or may be later in date than the rest of the series, for such weights and stamps were made for several hundred years. Glass No. 34, which was chosen for analysis because it was representative of the majority of the samples, has a unique composition very low in lime with a moderate alkali content. It would seem that a special glass was formulated for the manufacture of weights and stamps. This suggestion can only be confirmed when a much larger series of glass fragments is tested.

We must be careful to place the correct emphasis on the variations in glass composition. They can indicate different places of manufacture and sources of raw materials and thus give valuable information as to trade relationships of different regions and the constancy of ceramic traditions within a region. They can also be used to trace the improvements in ceramic compositions as experience and experimentally minded artisans developed more satisfactory products.

A thorough study of the manufacture of glass in any region and period must include a detailed knowledge of the composition and variations in the raw materials that could be found locally and of the ingredients that literary sources have indicated were used in trade and imported. Such a program, while ideal, is not very practical because of the time and cost involved. Egyptologists are most fortunate that a competent chemist like Mr. Lucas was able to spend many years of his life studying the technical processes used in ancient Egypt. His pioneer work is of tremendous value and will serve as a cornerstone for all future technical studies. While few people with adequate training will be able to devote their full energies to such work, it



(*Continued on page* 574)

THE ALTERABILITY OF OPTICAL GLASS

Editor's Note: A condensed translation from the original French of Bernard Long, *Verres et Refractaires*, 3 (2) 97-103 (1949), by N. J. Kreidl, Chemical Research Director, Bausch & Lomb Optical Co., Rochester, New York.

Bernard Long, the Director of the French Glass Institute and long time representative of France in international bodies concerned with glass, has subjected the problem of the alteration of surfaces of polished optical glass to careful examination.

His pertinent analysis includes compound formation with greases and their solubility. He investigates the usefulness of standard tests said to predict susceptibility to tarnishing and recommends F. L. Jones' dimming test.

He proposes the consideration of certain variations in this test. The study will be of interest to many American workers in the field of durability and is presented by The Glass Industry in somewhat condensed form.

Introduction

Except, perhaps, for the occasional exposure to transpiration, or fungus, optical glass is usually exposed to the attack of atmospheric agents, such as water, chiefly in the form of vapor and the acidic gases of the atmosphere, particularly carbon dioxide.

Glasses are usually considered rather inalterable but their normal deterioration in the atmosphere becomes manifest to all but wishful observers who attribute their observations to exceptional circumstances. If the surface has not been well polished, the lack of a striking base of comparison may create the illusion of inalterability.

Optical glass receives a polish of such excellent quality that the slightest alteration by atmospheric agents will not escape the attentive eye observing by transmitted light. The diffusion caused by this alteration interposes a "veil" between the light source and the eye (which causes the French to speak of "veil" where Americans speak of tarnish or scum, or less adequately of "stain" which latter word is more conveniently reserved to the result of acid leaching. Transl.).

Tarnish and Hydrolysis. The fundamental cause of tarnishing is humidity. CO_2 at a later time is modifying the texture to some degree. The action of humidity is a straight function of temperature. However, the presence of foreign matter, such as greasy material, greatly affects the phenomenon.

It has to be noted, too, that the surface of the polished glass is in a particular structural condition because of the polishing operation to which it has been subjected. The polishing process is not one of pure abrasion; in its final stages plastic flow may occur.[1] One will readily admit that the polished surface differs from that of a fresh fracture, if he considers that 1) The molecular structure has been modified by thermal agitation due to the polishing process. 2) The contact with tools and polishing materials will have deposited foreign matter. 3) The final cleaning must have been imperfect leaving greasy matter or even bringing along some more.

The dominant influence of humidity can be demonstrated by leaving a plate of borosilicate glass, as clean as possible, in an atmosphere saturated with humidity at 60° C. The glass will be found covered with droplets which become visible because of light diffused in the reflection of an intensive source. After drying, the glass exhibits a light greyish deposit clearly visible in reflected light and diminishing the reflection by several per cent.

The formation of these droplets may be explained in the following manner. The glass surface attracts water to complement its open structure. Alkali and alkaline earth ions in the network are replaced by hydrogen or hydroxonium (H_3O^+) ions: in other words, the glass is hydrolyzed. Alkali is liberated and silica gel formed according to the equation

$$Na_2O \cdot xSiO_2 + (1+y)\ H_2O = 2NaOH + xSiO_2 \cdot yH_2O$$

which is the schematic representation of a reversible reaction. Higher temperatures favor the right side of the equilibrium and load the scum caused by the droplets with an alkaline solution impregnating the silica gel. This alkaline solution is rapidly carbonated by the CO_2 of the atmosphere.

The alteration of the glass surface by liquid water differs from that described here. The alkali ions resulting from the hydrolysis are removed by liquid water leaving a transparent film of silica which grows with time and, on drying, forms a spot of uniform coloration. It is known that a spot of this kind in certain thicknesses reduces reflection losses. The attack by liquid water thus is not essentially different from that by diluted acids, which eliminate the cations adsorbed by the silica gel more efficiently and therefore diminish more rapidly the refractive index of the surface of barium and lead glasses.

It is useful to consider that the tarnish, which originally results from the sole intervention of humidity, undergoes a more thorough change if temperature and humidity vary. In fact, in the event of every evaporation, the alkali carbonates concentrate in the droplets and the silica gel, as well as the glass, is subjected to increased alkaline attack. In the play of successive evaporations and condensations, rapid growth of the deposit occurs until opacity is observed.

Iodeosin Test[2]. Until recently European (Transl.) catalogues of optical glass have listed the results of the iodeosin (Mylius) test applied to fresh fractures. The fracture was exposed for seven days to air saturated with water vapor at 18° C. The alkali liberated was transformed into an insoluble iodeosine of red color and determined colorimetrically. The classification was by milligrams of iodeosin per square meter of fresh surfaces: 1) 0-5 2) 5-10 3) 10-20 4) 20-40 5) more than 40. In the fracture both Si-O and N_2-O bonds are exposed and attract water. The chemical combination with glass produces OH groups and the fourfold coordination of silicon is reestablished. Hydrogen ions replace sodium ions.

Soon the discrepancy between the results of the Mylius test and the practical behavior of optical surfaces became apparent, especially in borosilicate and light barium crowns. If glasses of both families fall into the

[1] W. Klemm, A. Smekal, W. Loos, Nw. *29* 688-690, 710-711, 769-770 (1941); *30* 224-225 (1942).

[2] F. Mylius, Sprechsaal *36* 884, 924 (1903).

same Mylius class, the borosilicate types tarnish less. It is natural that fresh fractures of borosilicates, which contain more alkali, are more reactive with water. However, the greater deterioration of the light barium crowns escapes immediate explanation.

Provided the degree of tarnishing is directly related to droplet formation, which is reasonable, the polished surface of the borosilicate crowns may be called less hydrophilic than that of the light barium crowns. It is true that the modification of the structure by polishing is a good reason for discarding the iodeosin test as a basis for the prediction of tarnishing, but this does not solve the entire problem.

Grease. At least a partial solution may be found in the inevitable presence of traces of greasy matter. Greasy matter is present everywhere, in the polisher as well as in the solvents, the cleaning cloth and the atmosphere. Like water it is attracted by the surface to complement a molecular architecture different from that of the bulk.

A just polished surface exposes network modifiers Na^+ and K^+ as well as cations of higher valency such as Ba^{2+}, Pb^{2+}, and Al^{3+}. The latter favor the considerable adsorption of anions of fatty acids which confer non-wettability, make glass hydrophobic. It seems that the degree of non-wettability or hydrophobicity of the glass surface parallels, at least in part, tarnishing tendencies. It controls the contact angle of the droplets and influences transmission losses and scattering.

This explanation which was suggested by the work of W. Weyl[3] on the surface chemistry of glass, particularly on the adsorption of long chain hydrocarbons, such as trimethyl lauryl ammonium, is supported by the consideration of Lord Rayleigh's early work.[4] It suffices to recall the following experiment. A glass is cleaned until breathing forms a uniform deposit. It is then touched by a flame. Now the breath seems to leave the track of the flame untouched. Upon closer examination, this area is found equally wet, but it is covered by water in the form of a thin film which does not scatter light and, on drying, exhibits interference colors.

Another explanation has been formulated by Cojan[5] who, as early as in 1934, stressed the importance of traces of greasy matter. Two limited reactions develop on the surface: First, hydrolysis deplaces chiefly alkali in borosilicate crowns, barium in light barium crowns. Hydrolysis is intensified with increasing temperature. Second, the fatty acids are saponified. In the case of the borosilicate crown, a water soluble alkali soap is formed and in all probability, the silica gel impregnated with insoluble glass constituents remains responsible for the weak tarnish.

In the case of the light barium crown, an insoluble barium soap is formed. Its insolubility favors increasing saponification. The insoluble soap and the accentuated saponification are logical causes of the difference in behavior of borosilicate and light barium crowns.

Two conclusions may be derived from the preceding discussion: 1) The iodeosin test is clearly unsatisfactory in the characterization of glasses of widely different composition. 2) Traces of greasy matter, from polishing tools, poor cleaning, manipulation or atmosphere, are important factors in tarnishing.

Dimming and Exposure Tests. The needs for better characterization of the alterability of polished optical glass surfaces in the atmosphere has been manifest for thirty years. Elsden, Roberts and Jones[6] proposed to subject optical glass surfaces to an atmosphere saturated with humidity for 30 hours at 80° C. This test is adequately termed "dimming test."

The apparatus and the working procedure adopted assure precision, especially of temperature and humidity control. Quartz blanks, which must remain free from condensation, eliminate tests spoiled by inadequate cooling operation. Cleaning specifications are exacting in this test. The glass is washed with 50:50 mixture of water and double distilled alcohol, to which 2% of acetic acid have been added. The glass is dried with cloth cleaned by the following method: it is successively boiled in a solution of pure sodium oleate in distilled water, in pure distilled water until neutrality is registered by methyl orange, and in distilled water which is gradually acidulated by acetic acid.

After removal of the excess liquid the cloth is wound, wrung without finger contact, alcohol treated in a soxhlet flask, and finally dried in filtered air. During cleaning all manipulations are by pincers.

The "dimming test" led to the following classification: 1) Surface unaltered or altered very little. 2) Surface clearly altered. 3) Surface very seriously altered. These authors found good correlation of "dimming test" results and practical reputation in 28 glasses. They indicated that at a lower temperature a better separation could be expected. The strong desire for a suitable test predicting service alterability provoked the program carried out in 1937-38 by the Frankfort Arsenal in cooperation with the Bausch and Lomb Optical Co. and Mellon Institute.

The results are published in a recent release[7] and cover chiefly five standard glasses of the U. S. Army. The Arsenal decided that no other test was as significant as simple exposure without protection on a roof. Four samples each of three melts of each type to be studied were prepared. The samples were polished, washed in gasoline for one hour, wiped with tissue paper, washed with fresh gasoline for ten minutes, wiped with tissue paper, washed with alcohol for ten minutes, and wiped with a clean alcohol-drenched cloth. After three weeks of exposure, one sample of each melt was withdrawn and examined after cleaning with alcohol-drenched tissue paper. This was repeated for three more weeks, and after nine weeks the last two samples of each melt were examined. In a second series, the same samples which had been thus exposed were repolished and subjected to a two hour "dimming test" at 80°C.

The exposure tests classified the five types in this order:

(1)	Borosilicate Crown	1.5170 : 64.5
(2)	Light Barium Flint	1.5830 : 46.0
(3)	Medium Flint	1.6170 : 36.6
(4)	Barium Crown	1.5725 : 57.4
(5)	Dense Flint	1.6490 : 33.8

which is in accord with ordinary experience. According

[3] W. Weyl, Glass Science Bull. V 40-137 (1947).

[4] Lord Rayleigh, Nature *86* 416 (1911).

[5] "Tarnishing of Glass in Optical Instruments," June 1934.

[6] A. V. Elsden, O. Roberts, and H. S. Jones, J. Soc. Glass Tech. *4* 52-72 (1919).

[7] E. R. Rachel and C. A. Glaser, "Weathering Tests for Optical Glass," OPB No. 27, Dept. Commerce, Washington, D. C.

to the report, the glasses could not be distinguished by the dimming test because they were not sufficiently unstable. The Mellon Institute report is less schematical with respect to observations and conclusions, and stresses the dimming test and laboratory methods over exposure tests.

The author of the report, Dr. F. L. Jones, points out that in the exposure tests some samples remain unchanged, others assume blue, iridescent or brown surfaces in reflected light. This latter behavior is typical of glasses containing much lead or barium. He calls attention to these stains which are areas of diminished reflection and increased transmission. It is known that this alteration is caused by the dissolution of high index constituents leaving a surface layer of lower refraction. Jones is judicious in stating that the exposure test does not correlate with conditions of optical use. He postulates that a useful test has to predict the reaction with atmospheric agents under protection from rain. Consequently, he favors the "dimming test."

His experiments cover 26 Bausch and Lomb glasses which were exposed to saturated air at 50°C. for six weeks. The alterations were recorded by photographs of black numbers inscribed on white paper viewed through the samples. The degree of tarnishing was characterized by the definition of these numbers and measured quantitatively by the transmissivity as a function of time. The transmission increases or decreases with time because of the contrasting influence of the uniform dissolution of high index material (stain) and the formation of a diffusing layer of corrosion products.

The results demonstrate that the light transmission is more seriously affected if the reaction products are retained. In the exposure tests, their removal by rain causes mainly a harmless coloration in reflected light. The conclusion drawn in this release from the results obtained by the Arsenal and by F. L. Jones at Mellon are not very striking. It is disappointing that the release recommends 1) that no test for stability to atmospheric attack be included in the specifications, 2) that for the purpose of necessary comparison roof exposure tests be made for an appropriate time.

One must regret that of the work of F. L. Jones of real scientific quality and his pertinent observations practically nothing was retained by the competent military authorities in America who, like elsewhere, are inclined to look at physical problems too schematically, under the cover of a realism claimed missing in the scientific laboratory.

Jones was able to restate his views in 1941 after new and long experience.[8] He advocates a dimming test for 28 days at 50°C. as comparable with tropical conditions. Samples, 25mm. in diameter, 6mm. thick are polished, washed in gasoline, rinsed in distilled benzene, wiped with lens tissue, dried overnight wrapped in tissue and stocked in metal containers. After the removal from the test they are found covered with droplets, but do not exhibit any apparent damage. On drying at 50°C. for two hours they exhibit, under examination on a black velvet background, a light fog. The classification is by comparison with four emerald ground standards.

In this summary on laboratory tests suited to detect the aptitude of glass to preserve clear polished faces, D. Hubbard's hygrospicity test should be mentioned[9] 1.5 grams of glass powder is dried at 110°C. and subjected to a humid air stream under well defined conditions. The water becoming adsorbed during six days, noted daily. Hubbard hopes to draw significant conclusions from this test, the simplicity and rapidity of which he emphasizes.

It may be permissible to register some scepticism regarding the general interest in a test which is so remote from practical conditions and makes "tabula rasa" of important factors.

Conclusion. The problem under discussion presents two aspects, one practical and one theoretical. There is need to understand from a purely chemical viewpoint, the reactions of the material glass with water in the liquid and vapor states, under careful exclusion of interfering foreign matter. The iodeosin test satisfies this requirement inasmuch as it operates on glass having its original structure.

On the other hand, there is need to understand the reaction of glass conditioned by normal polishing and cleaning operations with an essentially variable atmosphere. This second aspect is of interest to the manufacturer and calls for a test which is a faithful image of reality. Evidently in this test commercially polished samples should be used and logically the reactant should be humid air. The problem is the fixation of characteristics and conditions to obtain in a limited time a result homothetic of practical performance.

Should the air be saturated or not with water? Should it be charged with greasy matter? Should there be alternation of humid and dry air? What temperature should be chosen? What should be the duration of the test? These are the questions which come to the mind. They are, perhaps, hard to answer without new and laborious experimentation. The "dimming test", the way it has been practiced by several people, seems to deserve confidence. It might be improved by finesses suggested by the preceding questions. It would be particularly desirable to find ways and means to avoid tarnishing entirely and to free human energies to battle on a more advanced front.

The present paper has deliberately disregarded the different forms of tests developed to predict sensitivity to stains: the stain tests of the Americans and English. The staining mode of alteration is less frequent and less obnoxious, it may even be beneficial, and should be treated rather in the context of a discussion of reduced surface reflections.

GLASS FIBERS AWARDED PIPE WRAP CONTRACT

Contracts have been awarded to Glass Fibers, Inc., for over 30-million square feet of underground pipe wrap to be used in all sections of the 857 mile crude oil pipeline to be constructed by the Mid-Valley Pipeline Company from Longview, Texas, to Lima, Ohio.

The material supplied will be the new "Vitron" underground pipe wrap recently developed by Glass Fibers, Inc. The Mid-Valley line will be one of the largest crude oil lines in the country requiring an investment of approximately $56,000,000.

[8] F. L. Jones, J. Am. Cer. Soc. *24*, (4) 119-122 (1941).
[9] D. Hubbard, J. Res. N. B. Stand. 365-375 (1946).

RECENT TRANSLATIONS OF RUSSIAN PAPERS OF INTEREST TO THE GLASS INDUSTRY

Abstracts of three papers which appeared in the Russian journal of the glass and ceramic industries.

Acceleration of Glass Making by Fluxes

L. I. Buneeva, V.V. Pollyak and I. D. Tykachinskii report in *Steklo i Keramika* (Glass and Ceramics) 1949, No. 2, p. 3, on a work carried out in the Moscow Glass Institute in which the time of glass formation was studied as function of temperature and the batch composition. Glass formation was considered to be complete when no quartz grains could be detected in a sample of melt viewed under microscope at magnification 56x. Because sodium sulfate is the main source of Na_2O in Russian glass, about half the experiments were done on sulfate batches, but only those experiments in which Na_2O was introduced as Na_2CO_3 98.5, Na_2SO_4 1.5% are reported here.

All the batches were calculated on the basis of:

SiO_2 71.5, Al_2O_3 1.5, CaO 8.0, MgO 3.0, and Na_2O 16.0 parts.

To this fundamental batch the following additions were made:

Glass No. 1 —none
No. 30 —1 part of fluorine (as CaF_2)
No. 50 —1.5 part of B_2O_3
No. 50a—1.5 part of B_2O_3 and 1 part of fluorine
No. 79 —B_2O_3 1.5, fluorine 1, MnO 0.3 and As_2O_3 0.3 part.

Glass melting was carried out either in a platinum crucible or in a pot of 300 kg. capacity.

The results obtained in platinum crucible are shown in Table I in which the heating time required for complete dissolution of quartz grains is expressed in minutes and the heating temperature is given in °C.

Table I

Heating time in min.

Glass No.	Heating temperature in °C 1350°	1400°	1425°	1450°
1	90.5	62.0	31.0	23.5
30	55.0	24.0	17.0	12.5
50	57.0	32.0	—	—
50a	22.0	18.0	13.5	10.0
79	51.3	29.5	—	—

Table II

Heating and fining time in hour and min.

Glass No.	Heating time	Fining time
1	14 hr. 25 min.	8 hr. 5 min.
30	9 hr. 25 min.	3 hr. 30 min.
50	10 hr. 10 min.	4 hr. 10 min.
50a	8 hr. 40 min.	3 hr. 30 min.

In the 300 kg. pot, glass was molten at 1420-1440°C and then fined at 1470-1480°. Table II shows the minimum time of melting and fining required for obtaining uniform glass.

It is seen that the total time of heating can be reduced from 22.5 hr. to 12 hr., i.e. almost by 50%, by addition of small amounts of B_2O_3 and CaF_2 to the fundamental batch.

Manufacture of Hardened Glass in U.S.S.R.

Large scale production of hardened glass started in U.S.S.R. as late as 1948. Miss G. V. Pototskaya describes the procedure adopted in the Moscow Automobile Glass plant ("Mosavtosteklo") in *Steklo i Keramika* (Glass and Ceramics) No. 1. p. 5 (1949).

Glass plates are introduced in the large electric furnace, the temperature of which is kept at 650°c (1202°F), and leave it when their temperature has reached 640°C (1184°F). The heating time depends on the composition of the glass and increases with the thickness of the plate by 4 sec. for every 0.1 mm. Thus, for a Fourcault glass containing SiO_2 71.35, Al_2O_3 0.4, Fe_2O_3 0.14, CaO 8.25, MgO 3.26, Na_2O 15.7 and SO_3 0.85%, the heating time is 200 sec. when the plate is 5.5 mm. thick and 240 sec. when the thickness is 6.5 mm.

After leaving the furnace the plate enters the narrow space (18 cm. wide) between two blowers. Each blower contains a checkerwork of nozzles, 5 mm. wide, distributed in 25 mm. distance from each other. The blowers move to and fro 120 times per minute, the amplitude being 25 mm. The air in the blowers has room temperature. Its excess pressure is 40-45 mm. of mercury for flat plates and 20-25 mm. of mercury for bent plates. The pump supplies the blowers with 150 cu. meters of air per minute. The forced cooling lasts 2.5-3 minutes.

Hardened glass must not break when hit by a 800 g. steel ball falling from the height of 1 meter. Usually, 70-75% of the plates are not cracked when the ball falls from 2 meters height either, and some samples are not destroyed by impact from the 3 meters height. Resistance to bending must be at least 1250 kg.-weight per sq. cm. and usually varies between 1550 and 1700 kg.-weight per sq. cm. The double refraction is 1.8-2.2 orders per 1 cm. of the beam path.

Role of Radiation in the Heat Conductance of Glass

The heat conductivity of solid glass and of molten glass near its "solidification temperature" is so small that the temperature near the bottom of a glass tank should have been much smaller than it is. The high temperature of the bottom layer of glass cannot be due to convection either because the viscosity of molten glass at the relevant temperatures is too great. It was assumed that the radiation from the flame space reaches the bottom of the tank through the transparent glass. However,

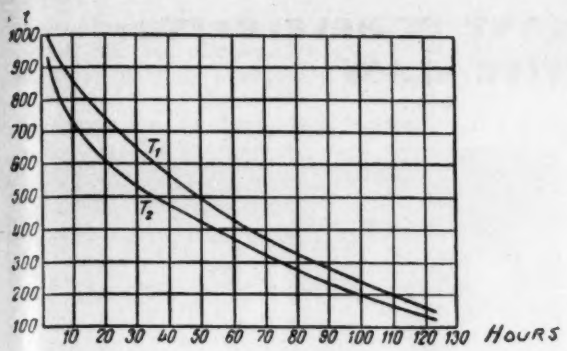


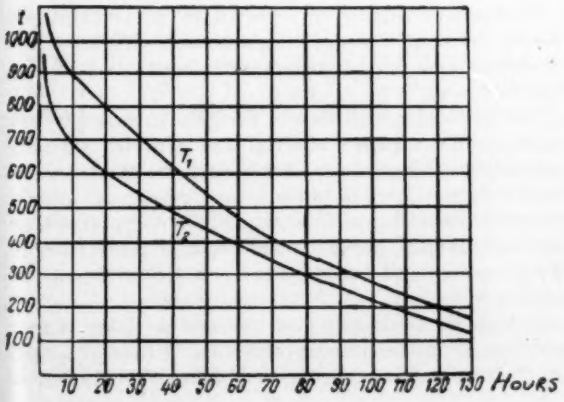
Fig. 1. Dark green.

the transparency of the glass for infrared rays seems to be insufficient for this explanation to be true. Miss V. V. Rodnikova, *Steklo i Keramika* (Glass and Ceramics) 1949, No. 3 p. 10, offers now another explanation. According to it, bottom layers of glass are heated by radiation not from the flame or roof above the glass but from the neighboring glass layers having higher temperature. The effect of this radiation wholly within glass on the heat transfer in it was studied experimentally.

Glass was made in pots having internal diameter of 81-86 cm. The height of glass in them was approximately 65 cm. As soon as the pots were withdrawn from the furnace, thermocouples were inserted in them. One thermocouple was placed near the center of the glass mass while another (or the others) was (were) fixed at the same level but near the wall of the pot. The distance between the central and the peripheral thermocouples was 30-37 cm. A few hours after the insertion of the thermocouples the pots were surrounded with sand to retard the cooling and the temperatures were read every hour for 120-140 hours.

To make clear the part played by radiation, colorless glasses were compared with dark glasses. The composition of the glasses used is not given by the author, but the colorless glasses are characterized as "heavy flint" and "borosilicate crown" while the colored glasses contained nickel oxide and were (a) dark green, absorption coefficient for 1 micron radiation = 1.7, for 2 microns radiation = 0.38, and for 3 microns radiation = 0.35, and (b) dark violet, absorption coefficient for 1 micron radiation = 1.0, for 2 microns radiation = 1.2 and for 3 microns radiation = 0.65.

Fig. 2. Dark violet.



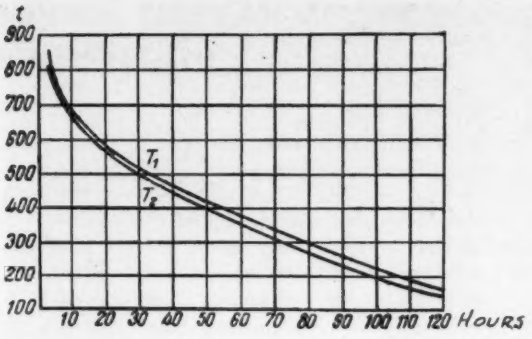


Fig. 3. Borosilicate crown.

Figures 1, 2, 3 and 4 show the temperatures of the central (T_1) and peripheral (T_2) thermocouples (in degrees centigrade) as function of cooling time (in hours). Fig. 1 is for the dark green glass, fig. 2 for the dark violet, fig. 3 for the crown, and fig. 4 for the flint.

It is seen that the difference between the temperatures in the center and at the wall remains almost constant or slightly decreases for the colorless glasses and passes over a high maximum for the colored glasses. For instance, this difference was after 15 hours cooling 210° for the violet glass and 27° for the flint, after 75 hours 70° for the violet glass and 54° for the flint, and after 110 hrs. 46° for the violet glass and 43° for the flint. When the temperature of the glass is below, say 300°, the difference $T_1 - T_2$ is almost independent of the transparency of the glass. This indicates that the heat conductance of glass below 300° has a mechanism different from that operating above 300°, and that the latter mechanism involves optical properties of glass.

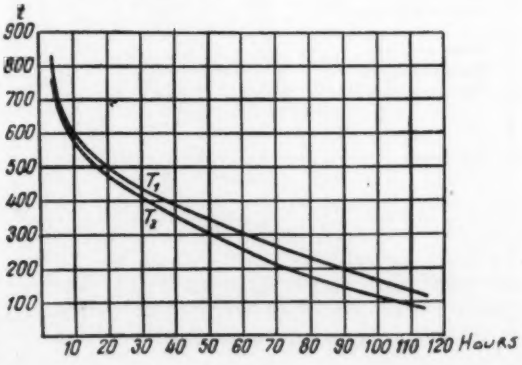
Table I

Heat conductance in $\frac{\text{cal./meter} \times \text{hour} \times \text{degree C.}}{}$	from cooling curve	theoretical
Dark violet glass	0.875	0.856
Dark green glass	0.78	0.8
Borosilicate	0.9	0.835
Heavy flint	0.67	0.66

The heat conductance below 300° may be identified with the usual heat conductivity in which radiation plays

(*Continued on page* 582)

Fig. 4. Heavy flint.



TEMPERATURE IMPORTANT IN DEVELOPING PHOTOSENSITIVE GLASS

Photosensitive glass pictures can now be produced in sizes ranging from miniatures used for jewelry to murals several feet square. These glass pictures are permanent and will resist weather and corrosion. Portraits can be preserved; religious pictures can be incorporated into church windows; house numbers can be placed on outdoor lamps with no fear of fading. Industrial uses include instrument dials and master charts and scales. They also make exceptionally clear lantern slides for projection.

The new photosensitive glass reproductions of high quality and workmanship are being produced by the H. & O. Company, Appleton, Wisconsin, and others, under a processing license issued for this purpose by the Corning Glass Works.

Development of glass as a photographic medium by the Corning Glass Works has imparted both permanence and a third dimensional aspect. The pictures, printed from ordinary negatives, are actually a part of the glass itself and are impregnated in a material that is practically ageless. The particles forming the image are dispersed throughout the thickness of the glass producing the effect of depth, thereby giving a third dimension perspective.

Theory of Photographic Sensitivity of Glass

A photosensitive glass is one which, upon exposure to ultraviolet light, undergoes a change such that a permanent photographic image can be developed within the glass by subsequent heat treatment. The photosensitive effect is not to be confused with the effect known as solarization. This latter effect is a direct coloration of some types of glass after they have been exposed to sunshine or other ultraviolet light for long periods.

Photosensitive glass compares to a photographic emulsion in that it contains a metal compound and sensitizers distributed throughout its mass. However, the glass differs from an emulsion in several important respects. Ordinary photographic emulsions are inhomogeneous suspensions of silver halide grains in a somewhat turbid medium. Photosensitive glass is a true solution of the compounds in an optically homogeneous medium having the properties of a typical clear glass.

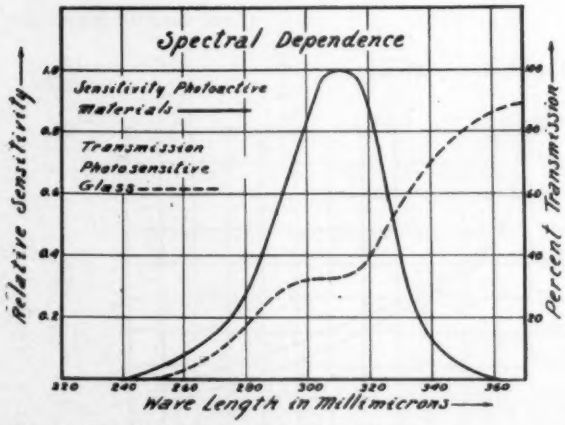


Fig. 1. Graph showing spectral dependence.

Fig. 2. Atlas carbon arc lamp, used for transposing image from glass or film negative to photosensitive glass.

In the new glass, the photosensitive ingredients are a part of the original glass batch which has been melted and formed by conventional methods.

After exposure to ultraviolet light, this glass remains unchanged to outward appearance. However, when it is heated to above the annealing temperature, metal particles constituting the photosensitive ingredients precipitate to form a developed image. The particles forming the image are much smaller than those in any known emulsion, including the Lippman emulsion (30 mm).

The colored particles in photosensitive glass are too small to scatter light. They are thus less than 10 millimicrons in diameter. It is believed in some cases they represent atomic dispersion of the metal. The lack of turbidity and of grain size makes the resolving power of photosensitive glass extremely high.

Light Sensitivity

Photosensitive glass is activated by a comparatively narrow band of ultraviolet light between 260 mmu and 360 mmu, and also by ionizing radiations such as X-rays and Beta-rays.

The sensitizing radiation is partially absorbed by the photographic negative material and also by the non-photosensitive ingredients of the glass, the shorter wavelengths being absorbed to the greater extent. By using a proper combination of light source, filter, exposure time and development, the color and depth of penetration of the image, as well as the intensity and contrast, can be readily controlled.

A high powered carbon or mercury arc lamp is generally used in the printing operation. Ultraviolet light of the required wavelength, as produced by the arc, is

passed through an ordinary photographic negative in contact with the photosensitive glass plate. After this exposure, the glass is ready for developing.

Temperature, an Important Factor in Developing Operations

To produce a visible image after an exposure to ultraviolet light, the glass is heated to a temperature between 580°C and 650°C in the furnace. In this temperature range the development requires from 15 minutes to an hour, depending on the exposure, type of color and depth effect desired.

Since glass is deformable in the temperature range previously mentioned, accurate temperature control is essential. Thermocouples placed in the developing furnaces detect furnace temperature changes. A Brown Instrument Company millivoltmeter-type controller precisely maintains this temperature at the desired value, which is shown in the illustration representing the deformation of glass as a function of time and temperature.

In technical and industrial applications particularly, deformation in the form of stretch or bending is objectionable in that decided inaccuracies result. In such cases, temperature control is of the utmost importance.

Permanence and Durability

Photosensitive glass provides a photographic medium which has all the attributes of ordinary glass. Glass is one of the most permanent materials available resistant to most chemical reagents and other influences, except breaking, and even this may be minimized by tempering.

The color of the image is believed to be perfectly stable, and will not fade or discolor with age.

Further exposure to ultraviolet light, after an image has been transposed into the glass, will produce no visible effect. Such an additional exposure could be made visible only by bringing the glass up to the developing temperature again. This is not likely to happen in any ordinary uses. Even if a photosensitive glass picture or design were to become scratched or etched by chemical action, the design is still within the glass and the surface could be repolished without removing it.

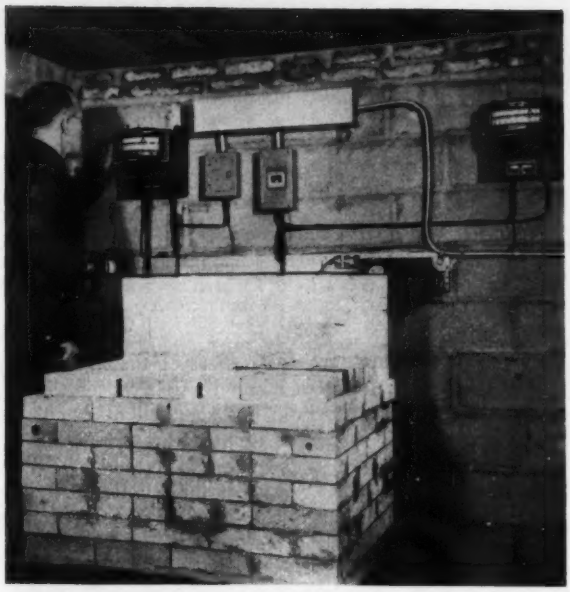


Fig. 3. Developing furnace, showing Brown millivoltmeter controllers.

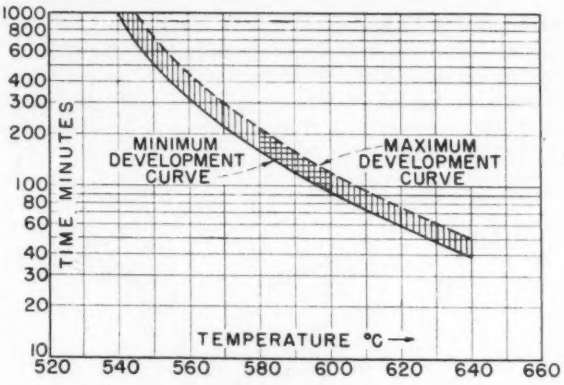


Fig. 4. Graph showing deformation curve.

L-O-F MAKES SALES APPOINTMENTS

The appointment of three field representatives to the Libbey-Owens-Ford Glass Company sales organization has been announced by G. P. MacNichol, Jr., Vice President in charge of Sales.

Hilary H. Smart was assigned to the Minneapolis office, Glenn T. Dunn, Jr., to the Dallas office, and Robert L. Brenneman to the Toledo office where he will cover the Cleveland territory.

Mr. Smart is a graduate of Harvard College and during the war served two years in the Army Air Forces as an aviation cadet. Mr. Dunn attended Southern Methodist University, Texas Christian University and Navy technical schools during his three years active service. Mr. Brenneman served four years in the U. S. Coast Guard during the war and prior to his recent appointment, was employed as a rendering artist in the L-O-F department of design.

FRED J. PETTY OF BALL BROTHERS DIES SUDDENLY

As this issue of THE GLASS INDUSTRY goes to press, it was learned that Fred J. Petty, Secretary of Ball Brothers Company, passed away suddenly at the age of 51 years. The cause of Mr. Petty's death was coronary thrombosis.

Identified with the glass industry for many years, Mr. Petty's sudden death comes as a shock to his many friends and business acquaintances.

● Herbert Young has been named industrial engineer at the Rossford plant of Libbey-Owens-Ford Glass Company. Mr. Young joined the firm 13 years ago and succeeds Melvin Burwell, who has moved up to management assistant to C. W. Davis, Vice President and General Factories Manager.

INVENTIONS AND INVENTORS

A Summary of Recently Issued Patents of Interest to the Glass Industry

Feeding and Forming

Hartford Feeder Mechanism. Fig. 1. Patent No. 2,479,-121. This patent is on a tube adjusting device for a Hartford-Empire Company single feeder, an early form of which is shown in Patent No. 1,760,254. Michael A. Koleda is the inventor.

At the first glance, the upper part of the figure appears to show the usual commercial single feeder which is too well known to require any detailed explanation here. It comprises a bowl 1, tube 6, plunger 26 and a rod 11-12 which supports the tube and by which it can be adjusted vertically by means of the handle 42. The particular features of this invention reside in the provision of means for adjusting the tube transversely of the bowl (this never having been provided) and a device for taking up the back lash caused by wear on the screw and nut by which the tube is adjusted vertically. When this back lash is present, the operator cannot tell whether a slight turn of the handle 42 has produced the desired movement of the tube.

The transverse adjustment of the tube is obtained by making the upper part of the rod 12 in two parts, the lower part 12a fitting into the tube 11 while the upper part 12b is eccentric and carries the arm 7 supporting the tube 6. The arm is secured to this eccentric by clamps 14 and 15 connected by cap screws 16 so that the arm can be held in fixed position. A set screw 18 engages a groove in the rod so that it can be held against rotation. Thus be loosening the screw 16 and 18, the eccentric can be turned to adjust the tube to the left or right as seen in the figure.

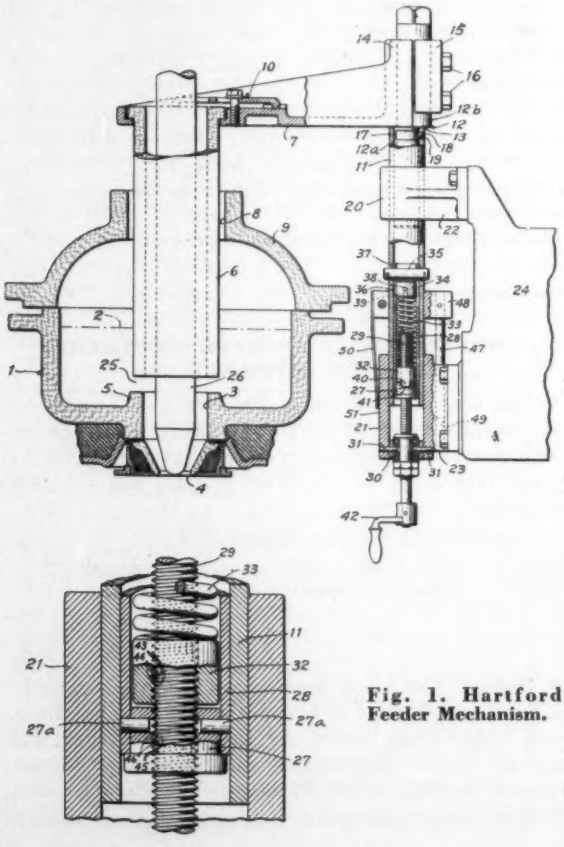


Fig. 1. Hartford Feeder Mechanism.

The following references are of record in the file of this patent: United States Patents: 1,760,254, Peiler, May 27, 1930, and 1,873,022, Peiler, Aug. 23, 1932.

Furnaces

Batch Feeder. Fig. 2. Patent No. 2,479,805. This feeder for delivering batch to the furnace was invented by George W. Batchell who assigned it to Toledo Engineering Company. The object of the invention is to provide a feeder which will not cause separation of the batch ingredients, which will prevent the passage of unmelted "islands" of batch and which will prevent loss through dust.

The figure is a sectional view through the longitudinal center of the feeder. The furnace F has a doghouse D and tracks 12 are supported by columns 10 and the buckstays 14 of the furnace. A carriage 15 has wheels 16 running on the track and it is mounted to oscillate about a pivot 20 riding on an arcuate track 22. A motor M causes the carriage to oscillate, reversing switches being placed so as to reverse the motor at each end of its run. The pivotal point of the carriage may be raised and lowered by connections to a shaft 55.

The batch is placed in a hopper 65 which is mounted for vertical adjustment and the discharge of batch is restrained by a baffle 70. The batch falls into a spout 80 and a worm 83 driven by the motor M delivers the batch to a furnace. An adjustable link 100 provides means for moving the delivery end 82 of the spout so as to deliver the batch to a greater or less depth below the surface of the glass in the furnace. The spout is chambered at 110

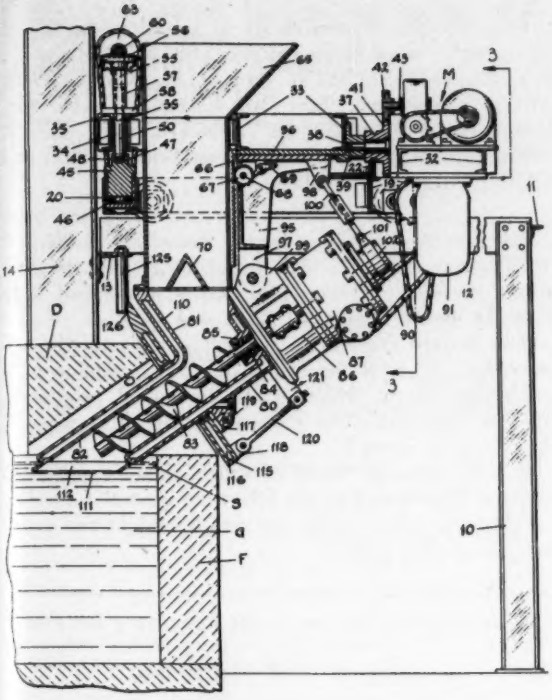


Fig. 2. Batch Feeder.

for water cooling. A renewable collar 112 may be replaced when worn out by contact with the molten glass.

By this construction the batch is placed within the body of molten glass on a continuously moving arc.

The following references are of record in the file of this patent: United States Patents: 1,761,229, Pedersen, June 3, 1930; 1,834,631, Mulholland, Dec. 1, 1931; 1,867,489, Bennett et al. July 12, 1932; 1,917,247, Good, July 11, 1933; and 1,922,827, Stewart, Aug. 15, 1933.

Glass Compositions

Porous Glass. Patent No. 2,480,672. This composition and method of forming porous glass was assigned to Socony-Vacuum Oil Company by Charles J. Plank of Woodbury, N. J. The glass so produced is useful as catalysts and for the formation of impervious glass of high silica content. This patent is related to U. S. Patents 2,106,744, 2,215,039 and 2,286,275 for forming porous glass from borosilicate glasses.

One of the two examples for making this glass is as follows: A mixture of 84 grams SiO_2, 80 grams B_2O_3, 20 grams $AlPO_4$ and 16 grams Na_2O was melted at 2300° F. After 30 minutes the temperature was raised to 2500° F. The melt was then quite fluid and was quenched in H_2O. A clear glass was obtained. This glass was readily attacked by boiling H_2O, being converted to a porous glass containing submicroscopic pores. The treatment by water at a temperature of from 90 to 100°C requires less than eight hours with glass from 2 to 3 mm. thick.

The following references are of record in the file of this patent: United States Patents: 2,010,836, Adams, Aug. 13, 1935; 2,100,391, Grimm, Nov. 30, 1937; 2,303,-756, Nordberg et al., Dec. 1, 1942; and 2,394,502, Weyl et al., Feb. 5, 1946. Foreign Patents: 428,329, Great Britain, May 10, 1935.

Fluophosphate Glass. Fig. 3. Patent No. 2,481,700. This is the invention of Kuan-Han Sun and Maurice L. Huggins who assigned it to Eastman Kodak Company. Reference is made to a co-pending application by the same inventors which discloses a glass formed by introducing phosphates in a fluoride glass as distinguished from the present invention.

The patent contains eleven tables which should be studied in order to gain a full understanding of the invention and these tables are too extensive for reproduction here. A general idea of the invention may be gained from the upper part of the figure in which the glass formation region is indicated for a ternary system including lithium and calcium fluorides and aluminum metaphosphate, the curved lines showing the approximate limits in mole per cent and in weight per cent. In this system a melting temperature of not over 850° C. is used.

In the lower part of the figure, n_D is plotted against v for some of the examples for which these properties are known. The areas of previously known glasses are indicated, and it is evident that the new glasses have optical values in fields not hitherto available. Area B indicates the region for the most common commercial glasses; C, the rare-element borate glasses disclosed in Morey Reissue Patent 21,175; D, fluoride glasses. It is to be understood that these areas are approximate only.

The invention is summarized in Claim 1 as follows: A fluophosphate optical glass consisting of the fused heat reaction product of a batch including by weight: lithium fluoride, 8 to 39 per cent; calcium fluoride, 0 to 39 per cent; and an aluminum phosphate, 40 to 76 per cent, the atomic proportion of fluorine to phosphor-

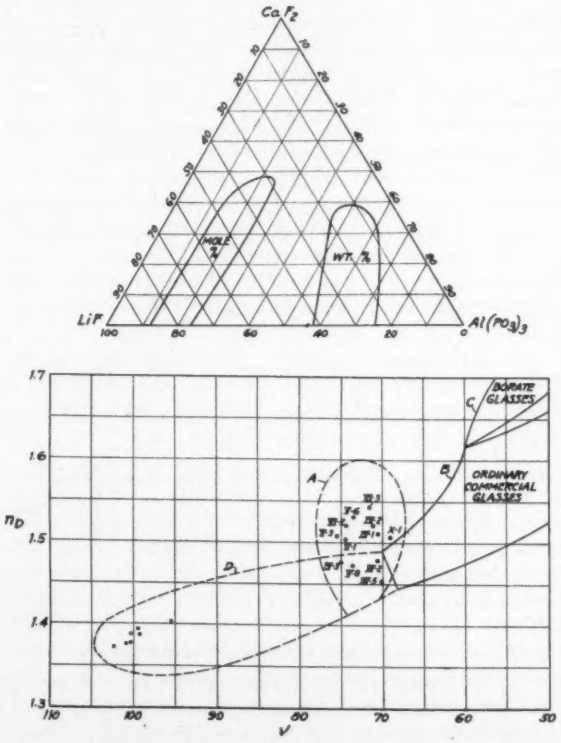


Fig. 3. Fluophosphate Glass.

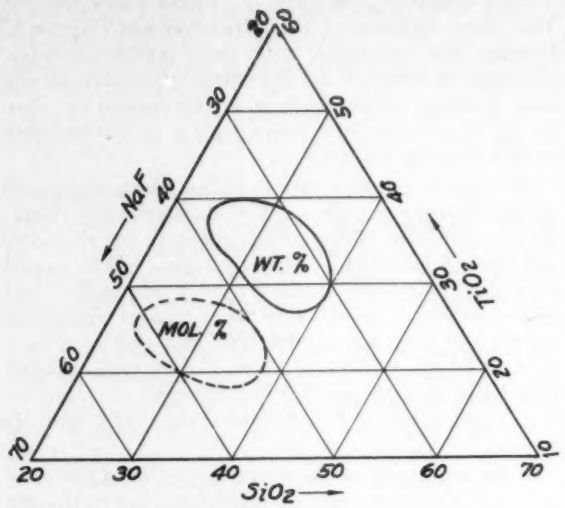


Fig. 4. Eastman Optical Glass.

ous being between 0.23 and 2.9, the remainder being compatible material.

The only reference of record in the file of this patent is U. S. Patent No. 1,303,268 to Drakenfeld dated May 13, 1919.

Glass or Porcelain Enamel. Patent No. 2,478,151. This batch composition was assigned to Norbert S. Garbisch, Butler, Pa., by George J. Bair of Corning, N. Y. It relates particularly to batches including aluminacious material.

There are several well known objections to the use of the most common alumina-bearing ingredients such as feldspar, etc. This invention contemplates the use of aluminacious material in a very finely divided condition and incorporating this material with silica and other insoluble batch material and mixing these while moistened and more or less fluid. The product is then dried which prevents any segregation of the ingredients.

The finely divided mixture of silica and glass from the grinding and polishing of glass may be well used as a source of silica and cullet. Iron may be removed from this by the process of the patent to McGregor No. 2, 182,384. The batch may be formed into nodules by the process disclosed in the Bair and Miller Patent No. 2,220,750.

The final composition of the blended mixture can be varied as needed. One spent grinding sand-clay mixture which has been found satisfactory when used for making a container batch is as follows:

	Pounds
Spent grinding sand-clay mix (90:10 mix)	1000
Dolomite	166
Soda ash	282
Salt cake	11

The water content of this batch may be approximately 17 to 25 per cent based upon the content of spent sand and clay. Glass from this batch contained 2.5 per cent alumina.

The following references are of record in the file of this patent: United States Patents: 2,084,328, Eells et al., June 22, 1937; 2,220,750, Bair et al., Nov. 5, 1940; 2,245,473, Garbisch, June 10, 1941; 2,313,566, McGregor, Mar. 9, 1943; and 2,366,473, Bair, Jan. 2, 1945. Foreign Patents: 2,921, Great Britain, 1899; and 472,027, Great Britain, 1937.

Eastman Optical Glass. Fig. 4. Patent No. 2,481,701. This patent relating to high dispersion fluosilicate glass is the invention of Kuan-Han Sun who assigned it to Eastman Kodak Company.

The ternary diagram in the figure indicates the approximate limits of the region of glass formation of a glass particularly desirable for its optical properties. Three systems are given in the patent of which one will do by way of example.

The approximate limits in which glass formation is attained is indicated in the following general formulas, in which the ranges of the per cent by weight and molal proportions are given:

Approximate Limits of Glass Formation Regions

System A.—NaF—TiO_2—SiO_2

	Wt. per cent	mol. per cent
NaF	29-38	40-51
TiO_2	26-39	19-28
SiO_2	26-40	22-38

A specific example of the general formula is as follows: W designating weight per cent, and M, mole per cent; and the values, where known, of n_D, the index of refraction of the D line, and of v, the Abbe value, being also given.

System A

Example No.	NaF W	NaF M	TiO_2 W	TiO_2 M	SiO_2 W	SiO_2 M	n_D	v
1	34	45.1	27	18.8	39	36.1	1.5961	32.71
2	33	44.1	29	20.4	38	35.5	1.614	31.1
3	37	48.9	31	21.5	32	29.6	1.608	30.6
4	32	43.2	32	22.8	36	34.0	1.6255	29.6
5	30	40.9	32	22.9	38	36.2	1.646	27.7
6	33.3	44.9	33.3	23.6	33.3	31.5	1.638	28.4
7	32	43.5	34	24.3	34	32.2	1.638	28.8
8	35	47.0	35	24.7	30	28.3	1.645	27.61
9	34	46.0	36	25.6	30	28.4	.....	....
10	38	50.8	38	26.7	24	22.5	1.6531	26.37
11	34	46.2	38	27.2	28	26.6	1.6680	29.95
12	31.8	43.2	33.6	24.0	34.6	32.8	1.6511	27.8

The patent gives in detail the optical qualities of the glass and full directions for practicing the invention.

No references were cited by the Patent Office during the prosecution of this application.

Porcelain Glaze Composition. Patent No. 2,478,645. This invention was assigned to General Electric Company by Ludwig E. Thiess and it relates to a glaze for electrical insulating bushings particularly those immersed in oil when in use. Heretofore trouble has been encountered from carbon deposits forming on such in-

sulators which reduced their efficiency and made frequent cleaning necessary.

A frit is prepared by intimately mixing and firing at about 1300°C., the following:

	Per cent by weight
Silica (SiO_2)	70.0 to 84.0
Manganese carbonate	6.5 to 14.5
Ferric oxide (Fe_2O_3)	6.0 to 12.0
Boric acid ($B_2O_3.3H_2O$)	2.0 to 7.0

The following glaze composition has been found to afford particularly good results from the standpoint of resisting the deposition of carbon when applied as a glaze to bushing porcelains:

	Per cent by weight
Potash feldspar	18.6
Whiting	16.3
Ball clay	23.0
Frit (above formula)	42.1

The glaze is applied in accordance with the well known methods. Certain modifications may be made within the scope of the patent.

The following reference is of record in the file of this patent: United States Patents: 250,465, Volbrath, Dec. 6, 1881.

Glass Wool and Fiber

Production of Glass Fibers. Fig. 5. Patent No. 2,481,543. Owens-Corning Fiberglas Corporation is the assignee of this invention by Charles J. Stalego. According to the patent fine fibers are made by feeding elongated glass rods into a gaseous medium having a temperature in excess of the melting temperature of the glass and having a velocity sufficiently high to draw out or attenuate the molten glass into fibers ranging from one micron or less to two and one-half or more microns in diameter.

Glass rods P are produced by a feeder 15 having orifices 16 through which the glass flows to rolls 17 and 18. These rods pass through a guide 32 into a high velocity blast B of intense heat from a burner 19. The

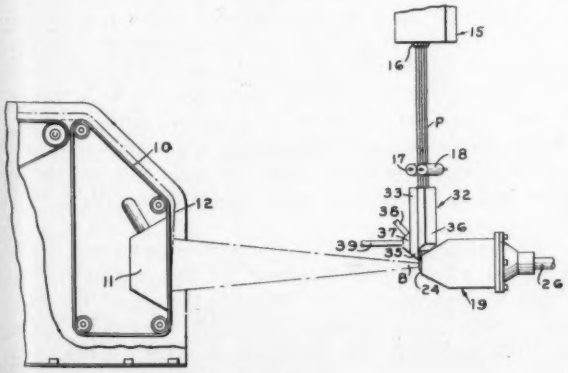


Fig. 5. Production of Glass Fibers.

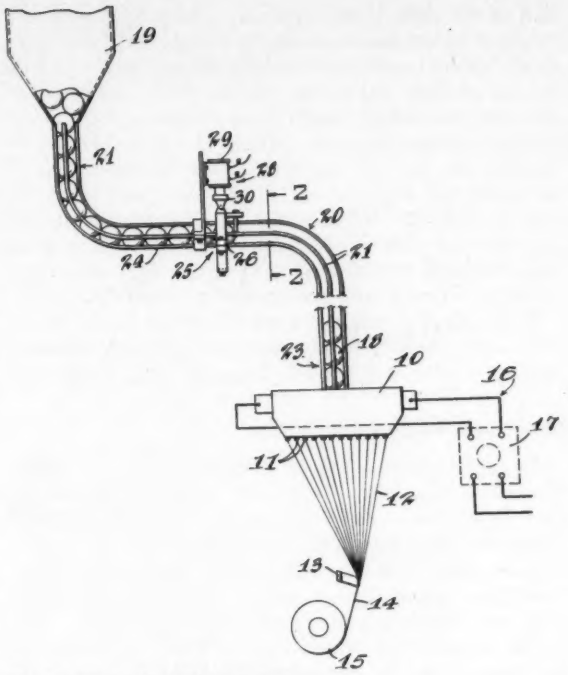


Fig. 6. Method of Making Fibers.

rods are fed into this blast B near the burner where the velocity and temperature of the blast is greatest. Suitable fuel for the burner is fed through a pipe 26.

The blast is sufficient to melt the glass rods P and to form fine fibers which are blown against a continuously moving perforated conveyor 10 having a suction chamber 11 on the back so that a mat 12 is formed on the conveyor. Means is provided for varying the width of the blast in accordance with the number of rods P being fed to it. Various other adjustments are provided.

The following references are of record in the file of this patent: United States Patents: 1,128,175, Morf, Feb. 9, 1915 and 1,157,984, Herkenrath, Oct. 26, 1915.

Method of Making Fibers. Fig. 6. Patent No. 2,482,071. Owens-Corning Fiberglas Corporation acquired this invention from Allen L. Simison of Newark, Ohio. The patent states that this method of manufacture produces fibers of uniform diameter which has heretofore been impossible for any great length of time.

In the figure there is indicated at 10 a melting chamber or feeder having orifices 11 in the bottom through which the molten glass flows in streams 12 which are gathered to form a strand 14 to be wound on a collecting drum 15. This drum is driven at a constant speed of perhaps 5,000 to 15,000 linear feet per minute and therefore the size of the fiber would be assumed to be constant but due to slight temperature changes in the glass, this is not so. The feeder 10 is heated from an electrical heating circuit 16 under control of a hand operated reostat 17.

Marbles 18 are supplied from a hopper 19 to a chute 20 the lower end 23 being vertical and containing a few marbles supported by the body of molten glass. As fast as a marble melts, another moves down into contact with the glass. The delivery of marbles to the vertical por-

tion of the chute is controlled by a gate 25 periodically actuated by an electric motor to admit one marble at a time. Means is provided for varying the rate of delivering the marbles and as the marbles in the portion 23 of the chute are clearly visible to the operator, he can judge the rate of flow from the orifices 11. If the column of marbles gets too low, the operator adjusts the reostat 17 to reduce the temperature of the feeder and hence the rate of melting. If too many marbles accumulate, he increases the feeder temperature. In this way a constant temperature is provided and, as a result, fiber of uniform diameter is drawn from the orifices.

The following references are of record in the file of this patent: United States Patents: 2,229,489, Bernard, Jan. 21, 1941 and 2,294,266, Barnard, Aug. 25, 1942.

Sheet and Plate Glass

Preparing Sheet Glass for Shipment. Fig. 7. Patent No. 2,476,145. This invention by James D. Gwyn and Carl B. Williams was assigned to Libbey-Owens-Ford Company. It is useful anywhere where there is a glass to glass contact but it is particularly useful in packaging sheet glass where it gives better results than the paper that was formerly put between adjacent sheets. This patent provides for depositing a protective coating on the glass sheets by attracting and holding a layer of wood flour or similar material to the sheet by an electrostatic charge.

The figure shows a conveyor 10 which carries the sheets 13 through an electrifying apparatus 14 and a dusting apparatus 15. The electrifying apparatus consists of a roll of silk cloth 16 which rotates in contact with the glass and in a direction opposite to the travel of the glass. The roll is driven by connections to a driven shaft 20. The sheet then moves to the dusting apparatus where dry wood flour of about 100 mesh is delivered from a hopper 22 to a chamber 26. The electrostatic charge on the glass causes a thin layer of wood flour to be deposited on the glass and retained there at least long enough for the sheets to be packed in a shipping box at the right end of the conveyor. It has been found that the protective coating will remain on the glass for ten minutes or more which gives plenty of time for packing. The coating remaining on the glass is readily removed and leaves no discoloration or other damage.

The following references are of record in the file of this patent: United States Patents: 820,717, Henke, Jr., May 15, 1906; 1,293,684, Brogley, Feb. 11, 1919; 1,698,845, Gustin, Jan. 15, 1929; 2,027,308, Schacht, Jan. 7, 1936; 2,128,811, Foster, Aug. 30, 1938; 2,163,642, Wallach, June 27, 1939; 2,173,032, Wintermute, Sept. 12, 1939; 2,174,328, Meston et al., Sept. 26, 1939; 2,247,963, Ransburg et al., July 1, 1941; 2,285,220, Morrell, June 2, 1942; and 2,320,674, Swift, June 1, 1943.

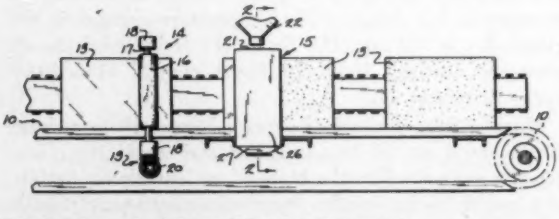


Fig. 7. Preparing Sheet Glass for Shipment.

Miscellaneous Processes

Glass Molds for Plastics. Patent No. 2,475,194. Arthur S. Nyquist and Edward L. Kropa assigned this invention to American Cyanamid Company. Glass has been used in the laboratory in molding thermosetting compositions where it has been found highly desirable on account of the high polish which it takes and its low cost. However, when working with acidic thermosetting compositions, the material adheres to the glass so that in some cases both the product and the mold are ruined.

These inventors have found that if the glass is coated with a solution of stannous compounds which are convertable to stannous oxide, the product may be readily removed without damage to it or to the mold. The patent gives an example in which glass plates, which subsequently were assembled to form a mold, were cleaned by treatment with a solution of dioctyl sodium sulfosuccinate, and allowed to dry by standing at room temperature. The plates were assembled, with the cleaned surfaces inward, to form a mold into which was poured a liquid, acidic thermosetting (heat-curable) composition which comprised, by weight, about 2 parts of an unsaturated alkyd resin having an acid number of about 50,

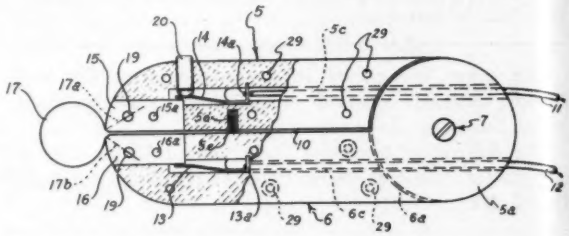


Fig. 8. Electric Tube Cutter.

specifically diethylene glycol fumarate sebacate, about 1 part styrene, 0.003 part hydroquinone (inhibitor) and 0.015 part of a polymerization catalyst, specifically lauroyl peroxide. The diethylene glycol fumarate sebacate was obtained by effecting reaction between 6 mols diethylene glycol, 5 mols fumaric acid and 1 mol sebacic acid. The mold and contents were heated for about 16 hours at about 50°C. and then for about 2 hours at 100°C. to polymerize the polymerizable or thermosetting composition and to convert it to a hard, polymeric or thermoset resinous state.

The mold adhered tenaciously to the solid resin, and could not be stripped therefrom either hot or cold.

However, when the plates treated as above were swabbed with an aqueous, acidulated stannous chloride solution, more particularly a solution composed of, by weight, 15% concentrated hydrochloric acid (about 37% HCl), 40% stannous chloride dihydrate and 45% water, rinsed with water, air dried, and buffed, specifically by rubbing with finely divided calcium carbonate, there was no adhesion between the parts, the mold was not damaged and the molded product showed an excellent surface.

The patent gives details as to temperatures and compositions adapted for treatment by this method. The following references are of record in the file of this patent: United States Patents: 1,353,152, Dinwiddie, Sept. 21, 1920 and 2,318,959, Muskat et al., May 11, 1943.

(*Continued on page* 570)

GJ Research Digest

Study of Glass Batch Melting by Radioactive Tracing

Glass is the result of the influence of heat on a suitable mixture; namely, the glass batch. Generally, less than one twentieth of the total time in a glass tank is required for the melting proper, but fining and homogenizing obviously must be influenced greatly by the melting phase. The answer to the question "what happens during the melting of a glass batch" may therefore be of certain importance to the glass technologist.

Many investigations, using accepted and standard procedures, have been made of this problem. With the advent of radioactive tracers, new lines of attack are opening up. Stig Lindroth (*Journal of the American Ceramic Society*, June 1949) describes one of these radioactive methods of tracing and its use in the study of glass batch melting.

In 1929, Hahn suggested the use of radioactive emanation producing tracers for investigations of powders. The method has been applied in 1) determination of surfaces and surface changes (e.g., melting) and 2) the study of diffusion phenomena in relation to transformations and chemical reactions. Briefly, the emanation method is based on the following principle: the addition of an emanation delivering element to the substance to be tested. A certain fraction, defined as the "emanation ability" of the emanation formed in the sample, will be released from the surface to an extent that depends on 1) the surface condition (the larger the surface, the greater the chance for an emanation at one recoiling in the body of the sample to reach the surface) and 2) the inner structure governing the diffusion of the emanation formed. The number of liberated emanation atoms is measured by their ionizing ability.

In the author's work the emanation method was used 1) to study the influence of minor constituents on the melting time of a soda-lime-silica glass batch and 2) as a first attempt to explain some of the reactions in a glass batch upon being heated.

The batch was prepared from precipitated silica, sodium carbonate and precipitated calcium carbonate. The batch was screened through 200-mesh, mixed and then screened through 150-mesh giving a glass of the composition Na_2O 16, CaO 10 and SiO_2 74%.

The minor constituents were passed through 200-mesh and 3% was mixed with the batch by screening three times through 150 mesh.

For an emanation determination, two drops of a radiothorium nitrate solution containing 0.1 millicurie per ml. (equivalent to 10^{-5} mg.) were added to 0.2 gm. of the moistened sample. After being dried and passed through 150-mesh, the sample was introduced into a small platinum boat, which was inserted into a horizontal electrically heated tube furnace. During heating at a rate of 10° per minute, nitrogen gas was passed through the tube at such a velocity that the highest possible galvanometer deflection was obtained at room temperature. The ionization current depends on the number of disintegrating emanation atoms. If the gas moves too slowly, disintegration will be more or less complete before the gas reaches the ionization chamber. On the other hand, too high a velocity will cause the main part of the emanation to decompose *after* passage through the chamber.

The furnace temperature was increased uniformly by hand regulation and the temperature was measured by a Pt-Pt-Rh thermocouple and a millivoltmeter. Time, temperature and galvanometer deflection were read each minute during the run.

The decrease of the grain surface was considered to be the index of melting rate and the temperatures on which comparisons of melting rates were based corresponded to the minimum value on the emanation curve after its final decrease. Values obtained by the emanation technique were compared with those obtained by a physical method in which the decrease in the height of the batch cones was measured. The agreement in general was good (comparison made on the deviations from the results obtained on the base glass rather than on the actual values). The results indicated that sodium chloride and ammonium chloride have the most favorable influence on melting rate and that fluorine-containing leipdolite lowers the melting rate more than spodumene or petalite.

The emanation curve for the base glass shows peaks at 400°, 625° and 850°C, the maximum peak being at 625°C. The peak at 400°C is due to the aragonite-calcite inversion. The peak at 850°C was ascribed to the melting of soda ash; i.e., unattacked sodium carbonate grains existing in the batch. As to the maximum at 625°C, the double carbonate $Na_2Ca\ (CO_3)_2$ begins to form at 600°C, according to Tammann and Oelsen. It is reasonable to suggest, therefore, that the decrease of the emanation value above this temperature indicates the formation of this compound.

The minor constituents affect the general behavior of the curve to a great extent. Additions of sodium chloride and ammonium chloride cause the disappearance of the soda ash peak; instead another maximum is visible at 800°C, coinciding with the melting point of NaCl.

It was concluded that in a study of initial melting reactions of a glass batch, the results obtained by means of the emanation technique parallel to a considerable degree those obtained by direct observation. The method appears to be a useful tool for studying such reactions and should thereby lead to a better understanding of glass batch melting.

● Theodore Haviland, II, President of Theodore Haviland Company, Inc. will serve as Chairman of the China and Glass Division for the 1949 Fund Drive of the Travelers Aid Society of New York. The campaign, now in progress, has a goal of $350,000.

G.C.M.I. TO HOLD FALL MEETING IN MIAMI BEACH

The 1949 Fall meeting of the Glass Container Manufacturers Institute will be held December 12, 13 and 14 at The Kenilworth Hotel at Miami Beach, Florida.

Meetings on December 12 and 13 will be under the auspices of the Board of Trustees for the purpose of receiving semi-annual reports from the nine standing committees and making them available to the industry generally. The semi-annual membership meeting, open only to glass container and closure manufacturers and allied and supplier companies that are regular members of the Institute, will be held on December 14.

JACKSON BROTHERS TO CONSTRUCT NEW GLASS PLANT

Jackson Brothers, Ltd. of Knottingley, England, has announced its plans for the erection of a new glass plant. It was expected that construction will commence on October 1.

The engineering of most of the plant is in the hands of King, Tauvedin & Gregson of Sheffield, England. The batch conveying system will be supplied by Convair Corporation, Pittsburgh, Pa.

DATES FOR THE ELEVENTH CONFERENCE ON GLASS PROBLEMS

The Eleventh Conference on Glass Problems will be held at the University of Illinois, Urbana, Illinois, on Thursday and Friday, December 8 and 9, 1949.

One day of the Conference will be devoted to metallurgical and mold problems, one-half day to heat treating problems and one-half day to quality control possibilities in the industry. The complete Conference program will be announced in the near future.

Any communications relating to the Conference should be addressed to F. V. Tooley, Professor of Glass Technology, University of Illinois, 208 Ceramics Building, Urbana, Illinois.

A. E. PAVLISH JOINS KELLEY ISLAND LIME

A. E. Pavlish has been appointed Technical Director of the Kelley Island Lime and Transport Company, according to the firm's announcement.

Mr. Pavlish was until recently a member of the supervisory research staff at Battelle Memorial Institute where, for fourteen years, he had been engaged in research in chemical technology. He is active in the work of the Electrochemical Society, the American Ceramic Society, the American Society for Testing Materials and the American Chemical Society.

CLEVELAND CRANE NAMES WORKS MANAGER

Milton T. Carleton has been appointed Works Manager of The Cleveland Crane & Engineering Company, according to an announcement made by the firm.

Formerly Works Manager of the Cleveland Division of E. W. Bliss Company for 14 years, Mr. Carleton has a background of over 35 years in all phases of heavy machinery manufacturing.

REPORT BY FORSTER'S GLASS COMPANY

The continued rise in production costs and the continued effort to achieve greater productive economy and efficiency are interesting points in the survey by Forster's Glass Company, Ltd., one of the leading British groups. Reporting on the year, Col. Charles E. Ponsonby, Chairman, gives the following interesting data on British costs and some comments on the problems facing the glass industry in Britain.

"The increased costs which have had to be met during the year have been considerable; coal, gas, electricity and transport have all advanced in price, and there have been increases in wages. This will be clearly seen from the following comparative figures showing how each £ we receive from our customers has been spent.

ANALYSIS OF EXPENDITURE DURING THE YEAR

	1948-49 s	1948-49 d	1947-48 s	1947-48 d
Wages, holiday pay, etc.	8	2	7	10¾
Raw materials and fuel (that is sand chemicals, cullet, coal and fuel oil)	5	1	4	7
Materials for maintenance and packing, road and rail transport, electricity, gas and water, and all other operating expenses	5	6¼	5	4
Taxation	0	5¾	0	10½
Depreciation and reserves	0	5¾	1	0¼
Dividends on capital (that is amount paid to shareholders after deducting income tax)	0	3¼	0	3½
	20	0	20	0

"By reason of the volume of our output and sales we have been able to carry these costs without any increase in selling prices, but our capacity to absorb continued increased costs in this way must be limited.

"After the fuel crisis of 1947, the directors decided to convert a portion of the plant to oil firing. We have experienced considerable delay on this project, due partly to the restriction of expenditure on oil-firing conversion schemes generally, and partly to the restriction on dollar imports. This work is now practically completed. The delay has meant that an additional burden has had to be borne by the existing plant already worked to capacity to meet the heavy demands for our products. In these circumstances, exceptional expenditure has had to be incurred on repairs and maintenance to ensure maximum output from our available plant in order to keep up deliveries to our customers."

G-E SCHEDULES DEMONSTRATION SERIES

In a move to spread wider knowledge of the new direct-recording x-ray diffraction and fluorescence-analyzing techniques throughout industry, General Electric X-Ray Corporation has scheduled a series of special demonstrations starting October 17 in its Cleveland office at 1783 East 11th Street.

The firm will have available one of its new direct-recording and fluorescence-analyzing machines.

CURRENT STATISTICAL POSITION OF GLASS

Glass container production for the month of August 1949, based on figures released by the Bureau of Census, rose to reach the highest single month's figure during 1949. Production was 8,661,555 gross, an increase of about 6½ per cent over the previous month's 8,108,218 gross. During August 1948, production was 8,890,189 gross, or 2½ per cent above August this year. Total glass container production thus far in 1949 has reached 60,582,951 gross, as compared with 66,866,104 gross produced during the same period in 1949—a difference of 9 per cent.

Shipments of glass containers for the month of August 1949 also rose to reach the highest single month's shipments for 1949. Shipments were 9,127,134 gross—15 per cent above July's 7,918,226 gross. Shipments for August were also above shipments for August 1948, which were 8,653,182 gross. The per cent increase over last August is 5 per cent. Total shipments for the first eight months of 1949 have reached 59,845,676 gross. This is 8 per cent below the 65,295,340 gross shipped during the corresponding period in 1948.

Stocks on hand at the close of August 1949 were 8,905,699 gross, as compared with 9,424,750 gross on hand at the close of July and 8,871,193 gross on hand at the close of August 1948.

GLASS CONTAINER SHIPMENTS

(All figures in Gross)

	August 1949
Narrow Neck Containers	
Foods	1,108,172
Medicinal & Health Supplies	1,049,477
Chemicals, Household & Industrial	628,818
Beverages, Returnable	480,295
Beverages, Non-returnable	5,525
Beer, Returnable	121,169
Beer, Non-returnable	321,834
Liquors	699,293
Wines	242,985
Toiletries & Cosmetics	550,607
Sub-total (Narrow)	5,208,175
Wide Mouth Containers	
Foods	2,412,099
Dairy Products	346,323
Home Canning	358,550
Medicinal & Health Supplies	264,938
Chemicals, Household & Industrial	99,601
Toiletries & Cosmetics	126,984
Packers' Tumblers	116,319
Sub-total (Wide)	3,724,814
Total Domestic	8,932,989
Export Shipments	194,145
Total Shipments	9,127,134

GLASS CONTAINER PRODUCTION AND INVENTORY

(All figures in Gross)

		Production August 1949	Stocks August 1949
Foods; Medicinal & Health Supplies; Chemicals, Household & industrial; Toiletries and Cosmetics	Narrow Neck	3,331,696	3,430,821
	Wide Mouth	2,708,987	2,344,406
Dairy Products		344,544	240,938
Home Canning		*185,819	364,743
Beverages, Returnable		492,460	629,395
Beverages, Non-Returnable		9,835	13,315
Beer, Returnable		103,152	610,165
Beer, Non-returnable		305,406	324,099
Liquors		828,875	578,409
Wines		235,638	275,988
Packers' Tumblers		115,143	93,420
Total		8,661,555	8,905,699

* This figure represents Fruit Jars only.

Automatic tumbler production for the month of June 1949 fell off 12 per cent to reach a total of 4,608,003 dozens. The previous month's figure was 5,242,474 dozens. During June 1948 production had been 4,357,283 dozens. Shipments for June also fell off to reach 4,993,005 dozens. However, this is only about 1 per cent below May's 5,054,771 dozens. Shipments for June 1948 were 4,742,233 dozens. Stocks on hand at the close of June were 8,154,076 dozens, as compared with 8,614,609 dozens on hand at the close of May and 8,154,597 dozens on hand at the close of June 1948.

Automatic tumbler production for the month of July 1949 continued on the downgrade and was reported to be 3,898,632 dozens. This is about 15 per cent below June's 4,608,003 dozens. Production during July 1948 was 4,036,003 dozens. Shipments for July were 4,197,489 dozens, as compared with 4,993,005 dozens shipped during June—a difference of close to 16 per cent. Shipments during July 1948 were 4,804,904 dozens. Stocks on hand at the close of July 1949 were 7,689,129 dozens, as compared with 8,154,076 dozens on hand at the close of June and 7,506,877 dozens on hand at the close of July 1948.

Table, kitchen and household glassware: Manufacturers' sales of machine-made table, kitchen and household glassware for the month of June 1949 were 3,367,659 dozens. This is about 8½ per cent below the previous month's 3,672,072 dozens. Sales during June 1948 were 3,350,944 dozens. Total manufacturers' sales at the close of the 12-month period ending June 1949 have reached 39,734,743 dozens as compared with 42,847,596 dozens sold during the corresponding period in 1948.

Manufacturers' sales of machine-made table, kitchen and household glassware for July 1949 were reported to be 2,528,315 dozens, which is about 24 per cent less than for June, which were 3,367,659 dozens. Sales during July 1948 were 2,977,409 dozens. Total sales at the close of the 12-month period ending with July 1949 were 39,285,651 dozens, as compared with 43,523,364 dozens sold during the same period in 1948.

• H. S. Hall has been appointed Assistant Manager of the Combustion Control Department of the Morgan Construction Company. Mr. Hall was previously the Fuel Engineer of the Lukens Steel Company.

THOMAS B. EAMES, OF GLASS BLOWERS ASSOCIATION, DIES IN PHILADELPHIA

Thomas B. Eames, 64, Secretary-Treasurer of the Glass Bottle Blowers Association of the United States and Canada, died in Fitzgerald-Mercy Hospital, Darby, Pa., following a heart attack.

Mr. Eames was a former Vice President and President of the New Jersey State Federation of Labor. He served 13 years as President of that organization. Born in Williamstown, he became a resident of Millville when a child. He learned the glass trade in the South Millville plant of the Whitall-Tatum Co. and was a member of Shekinah Lodge 82, FAM, Millville. At one time Mr. Eames was mentioned for appointment as New Jersey commissioner of labor.

When the national recovery act was adopted, President Roosevelt named Mr. Eames a member of the NRA board in New Jersey, a post he held until the board was abolished.

Surviving are his widow, Estella; a daughter, Mrs. Nora Price, of Kirklyn; a son, Norman; a sister, Elizabeth, Millville, and two grandchildren.

ANCHOR HOCKING PROMOTIONS

William V. Fisher, President of Anchor Hocking Glass Corporation, has announced a series of promotions in the company's Container Division and Tableware Division.

J. G. Callinan, Plant Manager of the firm's Tableware Division Plant Number 2, is being transferred to Los Angeles, where he will become Plant Manager of Maywood Glass Company, an Anchor Hocking subsidiary. James M. Fordham has been transferred from his post as Plant Manager of Anchor's container factory at Connellsville, Pa., to a similar post at the Salem, New Jersey, container plant.

In the Tableware Division, Norman Ogilvie has been promoted to Plant Manager of Anchor Hocking's Plant No. 1 at Lancaster, Ohio, succeeding G. F. Miller, recently elevated to the position of General Factories Manager of the Division.

Gerald Bay has been promoted to succeed Mr. Ogilvie as Assistant to the Plant Manager. Rodger McNaughton, formerly Assistant to the Plant Manager of the company's Tableware Division Plant No. 2, has been named Plant Manager at that factory. Frank Miller succeeds Mr. McNaughton at his vacated post.

● At the regular monthly meeting of the Board of Directors of Thatcher Glass Manufacturing Company, a dividend of $.60 per share was declared on its Convertible Preference Stock, payable November 15 to stockholders of record October 31.

Wherever you go...Whatever you see... Banner Lime *is in the picture!*

Banner Lime is definitely in the Indianapolis picture:

IN BUILDING—Indianapolis architects and contractors have long held Banner Lime in high favor because of its purity, uniformity and dependable results. It was used in the brick mortar and interior plaster for the Eli Lily Company Building (formerly the Curtiss Wright Building). Banner Lime was used outside and inside for a large addition to the Women's Prison, also for one of the finest Coca Cola Company buildings in the country.

Important also to Indiana are Purdue and Indiana Universities. Banner Lime was used for finish coat plastering in many buildings of these prominent institutions of higher learning.

IN INDUSTRY AND AGRICULTURE—Throughout Indiana, Banner Lime has been used for many years by the glass industry; and Banner Lime and Limestone for agricultural purposes have long been favorites for Indiana farms.

INDIANAPOLIS IN TODAY'S PICTURE: Known as the Crossroads of America, this thriving midwest city, the capital of Indiana, is noted for its fine schools, homes and boulevards and is proud of its excellent symphony orchestra. It is the home of the American Legion, Butler University, the Herron Art Institute, the Allison Jet Engine and the Fairmount Glass Co.

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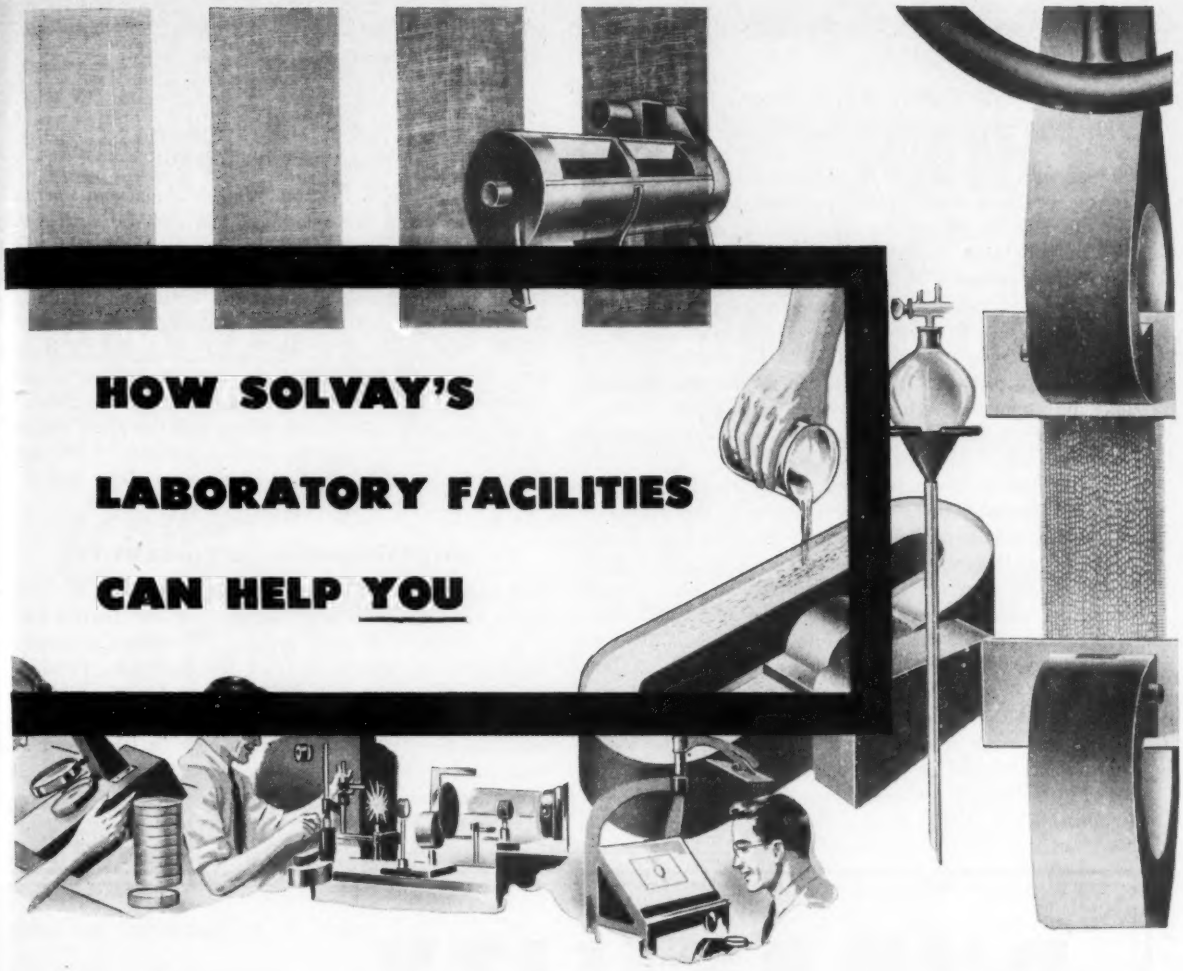

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Manufacturer . . . processor . . . convertor—*everyone* needs help sometimes in overcoming a production problem involving alkalies and associated chemicals. And at such times, SOLVAY Laboratory Facilities may be able to help you find the solution.

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INVENTIONS AND INVENTORS . . .
(*Continued from page* 564)

Electric Tube Cutter. Fig. 8. Patent No. 2,476,680. This invention is particularly adapted for use in connection with the manufacture of neon signs and it is the invention of Wyman D. Norgard of Denver, Colo. It is a portable cutter which produces a clean cut without the necessity of scoring the glass tube.

The apparatus comprises a pair of handles 5 and 6 pivotally connected at 7 so that they may be gripped by hand and held in the position shown in the figure against the tension of a spring 5e. The two handles are bored to receive conductors 11 and 12, one of which is connected directly with a brass insert 16 and the other may be connected with a second brass insert 15 by a button switch 20. The inserts are electrically connected with the ends of a nichrome wire loop 17.

In the use of this invention, a loop 17 of the proper size for the tube to be cut is attached to the inserts 15 and 16 by means of thumb screws 19. The loop is then placed over the tube and closed upon it by gripping the two handles. Current is then applied for the necessary length of time by means of the button 20. The current is then cut off but the loop 17 is still held in place by the handles. The operator then wipes the wire loop and adjacent glass tube with a piece of damp cotton, whereupon the tube will crack off with a clean cut.

The following references are of record in the file of this patent: United States Patents: 821,361, Hitner, May 22, 1906; 909,451, Pierce, Jan. 12, 1909; 1,130,373, Bright, Mar. 2, 1915; 1,435,985, Scohy, Nov. 21, 1922; and 1,892,814, Stahle, Jan. 3, 1933. Foreign Patents: 331,411, Great Britain, July 3, 1930.

A.C.S. PITTSBURGH SECTION MEETINGS

The Pittsburgh Section of the American Ceramic Society reported the opening of its 1949-50 with a stag outing which included a golf tournament in the afternoon, as well as plant trips through New Castle Refractories Co., Shenango Pottery and Universal-Rundle.

At a later meeting featuring "University of Pittsburgh Night", the program of the Section included 1) inspection of the laboratories, including the helium cryostat where temperatures near the absolute zero are obtained, studies on low temperature alloys and the glass research laboratory; 2) explanatory motion pictures of Dr. Alexander Silverman's collection of modern glass; and 3) a view of the collection itself.

OWENS-CORNING APPOINTMENT

The appointment of William H. Curtiss, Jr., as Advertising and Merchandising Manager of the Textile Products Division of Owens-Corning Fiberglas Corporation, has been announced by Harold Boeschenstein, President.

Mr. Curtiss joined the company in 1946, following service in the Navy and was formerly a sales representative in the Fiberglas branch offices in Cleveland and Detroit. In 1947, he transferred to Toledo as administrative assistant to the President. Mr. Curtiss will now make his headquarters in New York City.

DURABILITY

BORAX... the proper substitution of B_2O_3 for a part of the alkali in the batch will improve the chemical and thermal resistance of the finished ware.

• • •

Our representatives are prepared to discuss all the special advantages of B_2O_3 in glass.

PACIFIC COAST BORAX COMPANY

NEW YORK
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LOS ANGELES

A BIG "0" FOR OBSOLESCENCE

the ENEMY of Profitable GLASS PRODUCTION

for the answer to THESE IMPORTANT QUESTIONS . . .

1. How does our plant actually compare with those of competitors?
2. Would possible improvements and modernization alterations justify a complete shutdown for major changes?
3. Would it be practical to keep operating while "hot repairs" are made?
4. Or — would it be wisdom to completely rebuild and get full benefit of the latest developments in plant design and operating technique?

Consult TECO ENGINEERS

If that Big "0" for obsolescence rightly describes your glass melting equipment, it may be reflected in a "zero" on the profit statement.

The fast tempo of the glass industry today demands the ultimate in melting equipment.

TECO offers an abundance of field experience in the planning and rebuilding of glass plants and in remodeling and replacing obsolescent or inoperative equipment.

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NEW EQUIPMENT AND SUPPLIES

NEW GLASS FACKING METHOD

Sus-Rap Sales Company, 19 North Washington Avenue, Minneapolis, Minnesota, has announced national distribution of a new method for packing glass, mirrors, sensitive metal and plastic plates and other flat fragile objects.

The new suspension wrap idea was developed after more than a year of testing. Constructed of three layers of jute or kraft, Sus-Rap imparts both horizontal and vertical supports. It simplifies and speeds up packing of all merchandise for which it was designed and reduces packing and shipping costs, the manufacturer states.

The company reports that during the testing period sixty lights of automobile glass 30" x 16", were packed with Sus-Rap and sixty pieces of the same size in the old method were shipped to various destinations by truck, Railway Express and parcel post. These packages were reshipped to other points without opening the cartons and then returned to original shipping point. The 120 cartons were then opened and inspected for chipped edges and broken glass. The results found by the manufacturer were that every piece of glass packed with Sus-Rap came through without a chipped edge, but 30% of glass packed in the standard pack showed breakage and chipping of varying degrees. Sus-Rap is supplied in continuous roll form.

MAGNETIC SEPARATOR

The Bauer Bros. Co., 1782 Sheridan Avenue, Springfield, Ohio, has announced a new permanent magnetc separator which is in the form of a grate with magnetized Alnico bars and iron spacers.

The angular side supports are so designed that the grate can be laid in the bottom of a hopper or a floor opening and can be readily lifted out for cleaning. The rods are spaced midway between the magnetic bars to deflect the material and cause the streams to wipe the bars. The magnetic grates are made to fit all sizes of openings upwards from 8 inches square.

MULTIPLE POINT PYROMETER INDICATOR

Thermo Electric Company, Inc., Fair Lawn, N. J., has introducted a new model thermo electric pyrometer designed for indicating temperatures from one to six thermocouple locations at operating ranges from 75° to 400°F., 1000°F., 1600°F. and 2300°F., and minus 300° to plus 300°F., or equivalent centigrade scales.

The model, 10252 Indicator Assembly, is automatically compensated for cold junction temperature changes and instrument temperature resistance coefficient. The instrument scale is 3.17 inches long and movement is housed in a removable bakelite case.

A feature of this indicator is its specially constructed movement to provide accurate readings for these low temperature ranges of 75° to 400°F. and minus 300° to plus 300°F.

CATALOGUES RECEIVED

Selas Corporation of America, Erie Avenue and D Street, Philadelphia 34, Pa., has announced the publication of a booklet entitled "Speed Heating of Metals by the Gradiation Process".

The booklet describes the extension of gas combustion to new levels of usefulness in industrial processing, the objective of intensive research that has been applied successfully in production lines by more effective heat-transfer to metals under precise control and at high rates of speed.

Part 1 of the booklet discusses the gradiation method of speed heating which coordinates rapid metal heating with automatic equipment. Steel, copper and copper alloys are covered in part 2 with descriptions of metallurgical benefits illustrated by photomicrographs. Applications of the method, present and future, to heating for forging, brazing and hardening are discussed in parts 3 and 4, together with heating bars, tubes, billets and strip.

C. J. Taglibue Corporation, 614 Frelinghuysen Avenue, Newark 5, New Jersey, has issued a new 16-page catalogue, "TAG Laboratory Thermometers and Hydrometers", illustrating and describing the complete line of the company's thermometers and hydrometers for use in chemical and industrial laboratories.

Listings in this Catalogue 1100E include TAG standard grade A.S.T.M. and extreme etched stem thermometers and TAG certified A.P.I. hydrometers. Also contained in the catalogue are useful Fahrenheit-Centigrade conversion tables.

Chas. Taylor Sons Company, Cincinnati 14, Ohio, has announced the publication of a four-page illustrated bulletin which traces the development and discusses the properties and applications of Taylor Sillimanite (TASIL) Special Refractories. These are aluminum silicate refractories in which the alumina and silica are combined as mullite.

TASIL refractories are supplied as standard bricks, special shapes, cements, castables, ramming mixes and patching compounds to the glass, metallurgical, ceramic and chemical process industries.

L. J. Houze Convex Glass Company, Point Marion, Pa., has announced the availability of its booklet, "Houze and the Sun Glass Lens," which contains a review of the establishment of the firm and a resume history of the man responsible for its existence.

Glassmaking is discussed and the booklet closes with a warning by Dr. Robert H. Peckham, Associate Professor of Research Opthalmology at Temple University School of Medicine, to the effect that unprotected exposure to the sun's glare results in a reduction of the normal visual processes. Dr. Peckham reports that particularly hazardous is the reduction in the ability to see at night which may run from fifth to ninety per cent and which is prolonged by continued exposure of the eyes to the sun's glare.

The booklet published by the Houze company discusses the use and need for sun glasses.

Kahle Engineering Company, 1307 Seventh Street, North Bergen, New Jersey, issued a series of seven new pages for insertion in the Kahle catalogue covering a wide field and representative samples selected at random.

The seven sheets available and the contents of each are as follows: 1414, Button stem machine for cathode ray tubes, note of all its features, especially the positive wire clamps on each head; 1383, automatic filament mounting machine for miniature lamps of the butt seal type, mounting machines for standard and other lamps available; 1229, Automatic striping and painting machine for decorating glass and other items; 753, Alundum coating machine for coating the heater wire of electronic tube cathodes, the wire passing through the furnace 18 times; 1223, Bulb etch machine, inside or outside, often built as an automatic feature on sealing machines; 1233, Automatic finishing machine available for miniature, standard, large and special lamps; and 1262, Bulb tubulating machine, a newer, higher speed model, available also with 16, 24, 32 and 48 heads and combining automatic cut-off and glazing.

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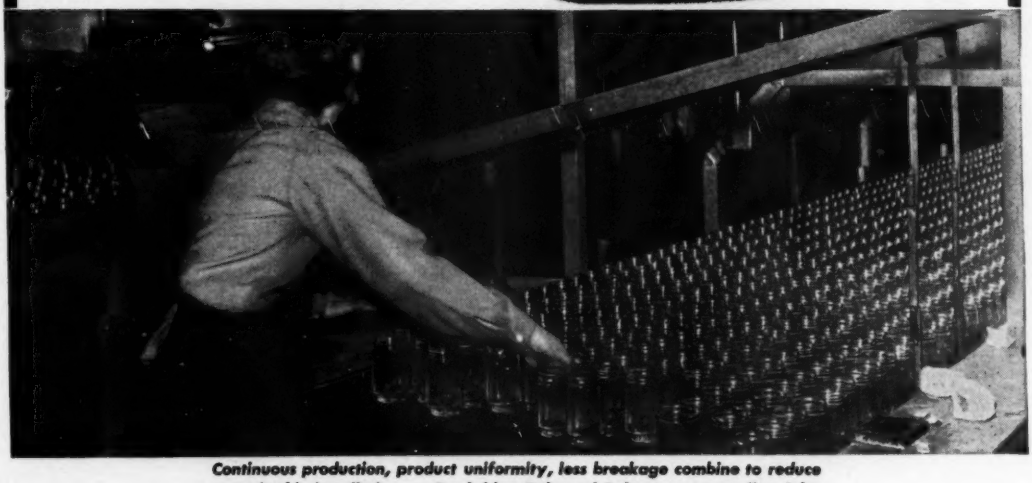

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OFFICES IN PRINCIPAL INDUSTRIAL CITIES

GLASS STANDARDS . . .

(*Continued from page* 552)

is to be hoped that many glass technologists and chemists will become interested in the problems of technological evolution and will actively cooperate with archaeologists.

Since technical studies will never be abundant, it is most essential that the material examined comes from well stratified deposits that have been competently excavated or from material, as in the present case, bearing a datable inscription. It is also important that the materials taken for detailed study are selected only after a large and representative group has been examined carefully and sorted by means of physical tests such as the measurement of the index of refraction and apparent specific gravity.

Summary

Sixteen eighth century Arabic glass stamps and weights made in or near Cairo that had been selected by Dr. Miles as representative of the series of over 200 in the collections of the American Numismatic Society were studied. The glass was not fired at a high enough temperature to melt all of the batch grains and eliminate the larger seeds and cords. This is especially evident in the heavy ring weights. It is estimated that the firing temperature was 2300°-2500° F. The techniques of manufacture of the weights and stamps were discussed.

The index of refraction and apparent specific gravity of each of the pieces was measured and chemical spot tests of the colorants used in the glasses were made. On the basis of these data the glasses were classified into five groups:

A Ten blue-green pieces with unweathered surfaces. A sample from one of these pieces was analyzed.

B One amber coin weight similar to group A except for color.

C One olive-green vessel stamp that may have been imported.

D Two weathered blue-green glasses, one of which was analyzed.

E Two deep blue coin weights colored with copper, manganese and cobalt.

The glass from group A had a unique composition,—very low in lime and high in R_2O_3. It is possible that the little lime present came in as an impurity in the sand rather than as an intentional batch ingredient. This glass was unusually resistant to weathering. It probably did not set up too rapidly when it was poured or ladled from the crucible, so the inscription on the iron dies could be impressed clearly on the glass. A special formula seems to have been used for the glass made in the Arabic Bureau of Standards.

The weathered glass that was analyzed resembled in composition several of the better glasses made in Egypt, Samarra and Pompeii.

The limestone occurring near Cairo is low in MgO. The glasses found in that region that have a high CaO:MgO ratio were therefore probably made locally. Natron was used to supply the alkali in the glass batches instead of plant ashes, it can be assumed, when the K_2O content of the glasses is low. The presence of small amounts of copper and manganese in the iron green glasses probably indicates that blue and purple frits or cullet were used as minor batch ingredients, perhaps for traditional reasons to ensure the success of the operation.

It is possible to examine a large number of glass fragments by methods such as those used in this report. Even museum display pieces can often be studied without injury to them. On the basis of such data a few fragments can then be selected for chemical analysis that will be truly representative of the glass made in a region at a definite time in history. In this way our knowledge of the technology of ancient glass production can be expanded.

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STAINED GLASS CENTER OF COURT SUIT

A mysterious appearance of some whitish stains on every piece of glass of some 469 cases shipped in wartime from Montreal over a long sea and land route to Bogota, Colombia, has become the subject of a court case in Montreal where Mr. Justice Arthur I. Smith said the offending stains were not proven to have made their appearance when Manuel Gonzales Brun, Bogota merchant, received delivery of the glass at New Orleans, on the first leg of the trip to the South American Republic.

Brun had sued the Hobbs Glass Co. of Montreal, shippers of the glass, for $11,994.72, claiming that it had become stained through the use of excessive alkali in the manufacturing process or by faulty storage or packing. The company denied the allegation and suggested that the defect was caused by climatic or atmospheric conditions on the long voyage to South America and long after it had passed out of the company's control.

In the evidence produced, Mr. Justice Smith could find no proof that the glass was defective when it left Montreal or that the shipment had been improperly packed. There was evidence, on the other hand, that the kind of defect complained of could have occurred from weather encountered on the long sea and land trip. The glass had been accepted by the consignee at New Orleans without inspection and in regard to packing, it was shown the shippers had observed the specifications given to them. Accordingly, the action for damages was dismissed.

• Dominion Glass Co., Ltd. has declared a regular quarterly dividend of 25 cents per share on the common stock and 35 cents on the preferred, both payable Oct. 15 to shareholders of record Sept. 27, 1949.

• Dunbar Glass Corporation has retained Jack B. Weil, Public Relations Consultants of Chicago to formulate and direct an educational program designed to give both industry and the consumer a better understanding of the applications and diversified uses of molded glass.

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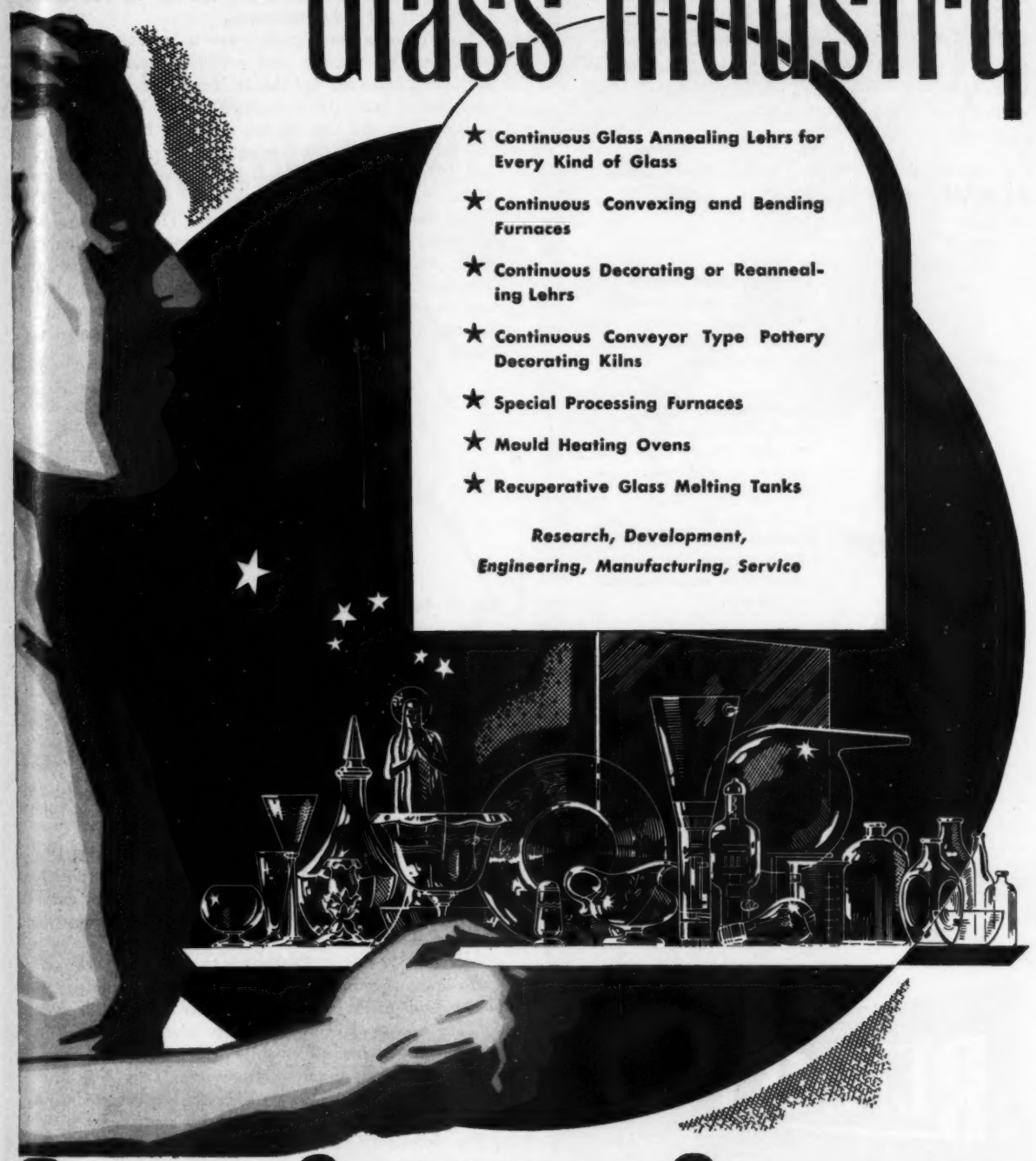

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OPTICS OF CURVED GLASS . . .
(*Continued from page* 547)

responded to a variation of 42 feet at 1000 yards. The importance of this variation in gun sighting is apparent. This panel had a flat section joined to a curved section in a manner which was prompted by the desire for good streamlining. The sighting position was located directly beneath the flat end of the panel.

Fig. 6 shows the deviation due to curvature as calculated for this window and several modifications. The deviations observed for the original window were somewhat better than the calculated values because the actual window did not change abruptly from the flat to the curved section. By mathematical trial and error, it was found that an elliptical bend gave a very uniform deviation, and the performance of actual panels followed the calculations very closely. (In the case of one elliptical design the calculated range of deviation was under 2 minutes, while the range observed in test samples was within 4 minutes.) Since a constant deviation can be easily compensated by a single adjustment of the sighting equipment, this type of sighting panel was found to be highly satisfactory.

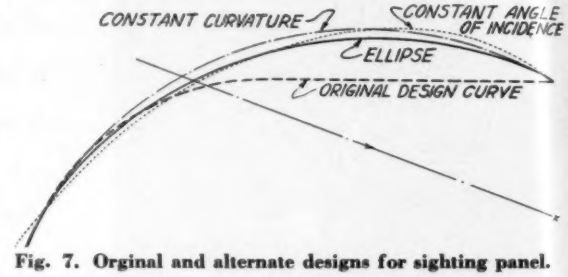

Fig. 7. Orginal and alternate designs for sighting panel.

Fig. 7 shows the shape of the original panel and the several modifications. It will be seen that the elliptical shape should not offer a serious objection from the standpoint of airflow.

The original sighting panel illustrates a typical faulty optical design. Here the most obvious visual defect occurs where the curvature changes suddenly. Abrupt changes in curvature are frequently a source of poor optics.

The development of the modified elliptical panel illustrates the magnitude of improvement which is possible through the application of optics in the design of curved glass windows. Here, through the analysis of curvature effects alone, the range of error in actual panels was reduced from 42 feet at 1000 yards to 4 feet at 1000 yards.

However, this improvement will only be obtained for observations made from the particular location for which the design was developed. From other points the improvement will be less effective. In general, the use of curved glass for windows will result in some loss in the optical performance. This loss should be evaluated along with the desirable features of curved glass.

The deterioration in optics may prove to be unimportant when the radius of curvature is sufficiently large, or the line of sight is approximately normal to the glass. However, to be assured of the best combination of performance characteristics, the optics as well as other architectural features should be considered in the design of curved glass windows.

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UNITED PROVINCES GOVERNMENT AIDS INDIA GLASS EXPANSION

Recent archaeological discoveries and excavations have established the fact that glass vessels and ornaments were in use in India even in the ancient times. Enamelled glass was widely used and glass beads were fashionable and popular.

Manufacture of glass on modern lines, however, dates from the nineties of the last century and a factory at Telegaon in Poona was the pioneer in giving technical training to workers. This factory was started by the collection of one piece from each contributor and was known as the Paisa Fund Glass Works. The war in 1914-18 gave some impetus to the factory as imports from European countries stopped. During this period 16 new factories sprang up and the Indian Munitions Board encouraged the manufacture of glassware, but after the war the Indian factories had to face severe competition from foreign firms.

A number of new factories for the manufacture of hollow-ware, bottle-ware and one for sheet glass were established. Besides meeting domestic demands, an appreciable quantity began to be exported. During 1934-37 there was a phenomenal increase of 245% in exports of glassware. Progress was maintained throughout the war period. From 17 factories employing 2,318 workers in 1939, the number rose to 47 with 8,950 workers in 1941 and by 1945 there were 116 factories employing nearly 20,000 workers. The chief importers of Indian glassware are Ceylon, Malaya, Arabia, Iran, Bahrein Islands and Aden.

A noteworthy feature of the progress made is the expansion of the manufacture of sheet glass. The producing units are well equipped with tank furnaces or pot furnaces. Scientific and hospital equipment, thermos flask refills, and shells for electric bulbs are also manufactured.

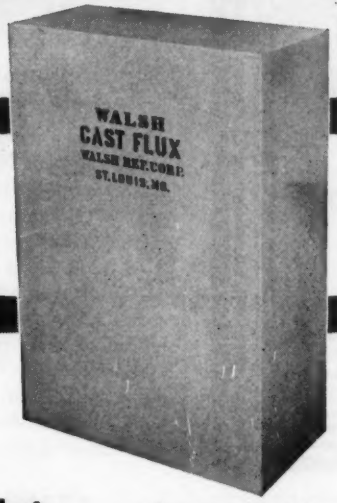
In United Provinces the industry has received a good deal of assistance from the government. The Glass Technology Institute of the Government has trained a large number of men in the manufacture of fancy goods. The Benares Hindu University has also given training in glass technology to aspiring young men. With the establishment of the Central Glass and Ceramic Institute of Jadavpur (West Bengal), systematic research is being conducted on methods of improving the quality, design and finish of Indian glass products.

Besides the big factories, fancy goods are produced by cottage units which are concentrated around Ferozabad, a small town in the U.P. Glass bangles and beads, which are very popular and much in demand both by women and children, are manufactured there. An impetus has recently been given by the U. P. Government to this cottage industry which employs over 10,000 people. Manufacturers have been helped to form their own co-operatives for getting raw materials and for marketing their product.

The glass industry is highly localized in the United Provinces because of the availability of raw materials and the existence of skilled workers. Out of a total of 137 factories in India, the U.P. has over 87 factories, West Bengal 21, Bombay 12, East Punjab 6 and the rest 11.

Slash...

MELTING COSTS 5 WAYS WITH WALSH CAST-FLUX TANK BLOCKS



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Other Walsh products for the Glass Industry include:
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POLYCHROME GLASSWARE WITH GOLD GROUND SHOWN AT ITALIAN EXHIBITION

At the last Biennial Exhibition of Venice, the firm, Barovier & Toso of Murano, exhibited a very interesting collection of polychromous glassware with gold ground. The glassware was produced by Ercole Barovier, one of the company's owners, by means of a new technique.

Mr. Barovier's glassware belongs to two different types of blown glass which he has called "Corinth" and "Damascus". The "Corinth" glasses are obtained by the alternation of little multiple opaque rods with stripes of an even color. The "Damascus" glasses, to the contrary, are the result of the blending of a kind of colored filigree with murrhine beads, which is a well received technical innovation in the industry of Murano glassware.

FRANK H. WHEATON HONORED AT FIFTIETH YEAR CELEBRATION

Frank H. Wheaton, President of the T. C. Wheaton Company, was honored by three thousand people celebrating his fiftieth year with the company. A new warehouse, recently completed, was filled to the doors for a program of tributes and recollections of the last 50 years of the glass business.

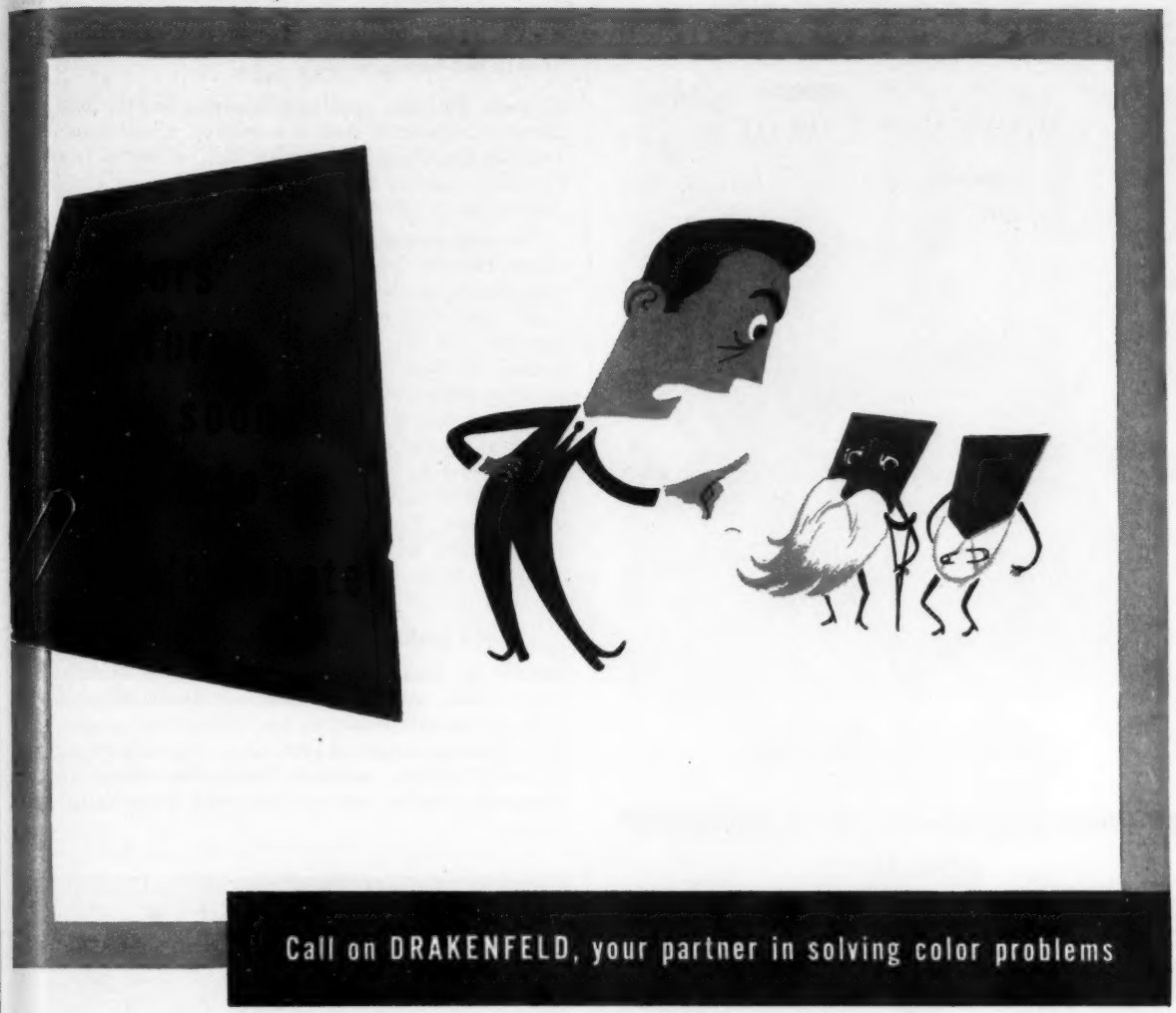
Dr. Theodore G. Wheaton, Frank Wheaton's father, founded the T. C. Wheaton Company in 1888. Frank Wheaton reported for work at his father's glass factory in 1899. The firm continued to grow with additions of a factory in 1901, a mold and machine shop and blacksmith shop, and in 1909 the eight-pot furnace was replaced by a large continuous tank. Mr. Wheaton became President of the company upon the death of his father in September 1931. Frank Wheaton, Jr., is also active in the business.

C. GEORGE LESUEUR DIES

C. George leSueur, Manager of the Export Department of Wyandotte Chemicals Corporation, passed away at Harper Hospital, Detroit, where he had been a patient for the past month.

Mr. leSueur had just earned his 25-year service watch from Wyandotte. For many years he had headed Canadian sales for the firm and was formerly a director of the U. S. Alkali Export Association.

Mr. leSueur was a member of the Detroit Athletic Club, Economics Club, Foreign Trade Club of Detroit, the World Affairs Committee of the Detroit Board of Commerce, Wyandotte Masonic Lodge and was a Shriner.



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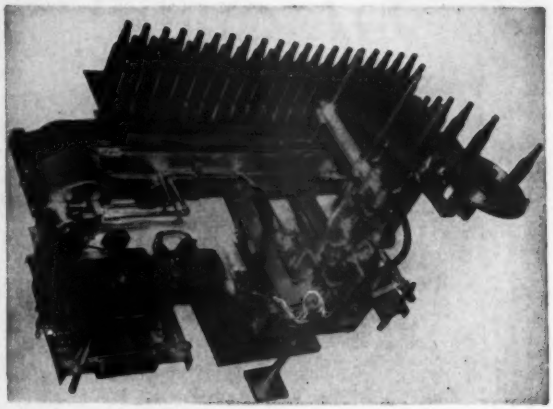

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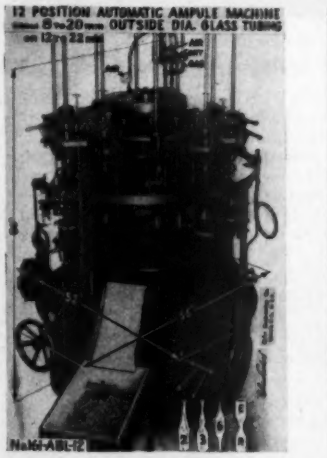

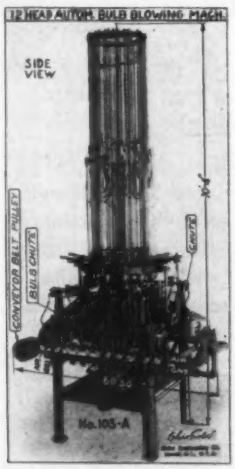

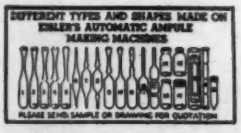

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RECENT TRANSLATIONS OF RUSSIAN PAPERS . . .
(*Continued from page* 557)

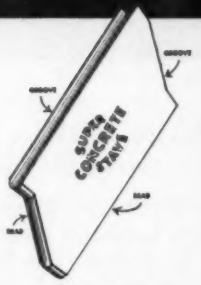
no part. This was confirmed by comparing the heat conductance calculated from the cooling curves near 170° with the theoretical heat conductivity calculated from the customary factors for the oxides making up the glass. Table I shows this comparison.

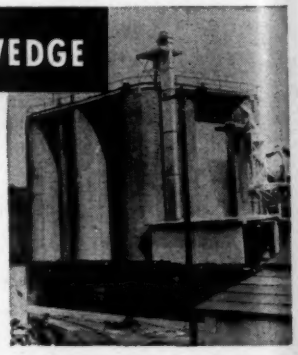
The total heat conductance calculated from the cooling curves remains below one in the dark glasses up to the temperature of about 800°. Unfortunately, this calculation is not exact at high temperatures because the heat capacity and specific gravity of the glasses used were known at room temperature only. However, this uncertainty cannot explain away the difference between the total heat conductances of dark and colorless glasses. The heat conductance of the latter starts to rise with rising temperature at about 300°; it reaches the value of 2 below 500° and is at 800° more than 10 times that of dark glasses. These high values must be due to heating by radiation which both originates and is absorbed within the glass.

SYLVANIA MAKES APPOINTMENT

Charles H. Goddard has been appointed Manager of Utility Sales, according to an announcement made by Sylvania Electric Products, Inc. In his new assignment, he will be in charge of sales of all lighting equipment to municipalities, railroads and other transportation companies, central station sales and large utility accounts.

THE STAVES WEDGE





As you will see in the illustration of a Neff & Fry Super-Concrete Stave, the ends are mitered and the edges are grooved and beaded. Because of this patented design, each stave interlocks with six contiguous ones, forming a firm and symmetrical structure.

The ends of the staves are further supported by heavy galvanized steel rings drawn tight around the zigzag joints. Between these rings, as many others are placed as needed to resist the calculated lateral pressure.

Neff & Fry Bins are used for handling and storing aggregates, ashes, cement, chemicals, cinders, clay, coal, coke, fertilizer, grain, gravel, lime, limestone, minerals, ore, sand, sawdust, scrap, seeds, slag, water, wood pulp, and many other materials.

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Used Gas Fired Simplex Annealing Lehr, 116 feet long, with 48" belt, with Brown temperature control equipment. This may be inspected at the Okmulgee, Oklahoma, plant. Get in touch with Ball Brothers Co., Muncie, Indiana, office—Kinzie.

HARBISON-WALKER STAFF CHANGE

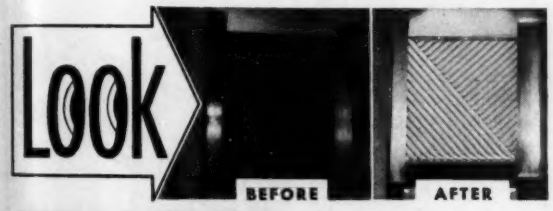
D. B. Hendryx, who has been chief engineer for Harbison-Walker Refractories Company for the past 21 years, has tendered his resignation in order to establish his own office for engineering and consultant work. He will also do some consultant work for Harbison-Walker.

R. P. Snyder, who has been associated with the firm and the Northwest Magnesite Company for the past 16 years, will succeed Mr. Hendryx as chief engineer.

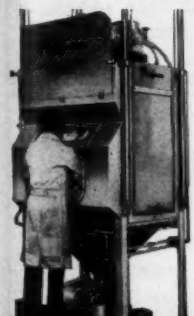
INNIS, SPEIDEN ELECTS NEW PRESIDENT

W. H. Sheffield, Jr., has been elected President and General Manager of Innis, Speiden & Company. Mr. Sheffield, formerly Vice President of the firm, was elected to fill the post left vacant by the recent death of his father, W. H. Sheffield.

At the same meeting of the Board of Directors, R. C. Palmer, Secretary of the company, was elected a member of the Board, and D. S. Cushman, formerly Assistant to the Vice President, was named Assistant to the President.



HYDRO-FINISH
Cleans Glass Molds Faster



Pangborn Hydro-Finish rapidly cleans glass molds and, as the photos show, leaves molds bright and ready to use. Little or no hand polishing is necessary. Sharp edges and contours are maintained. Extremely fine mesh abrasive suspended in water is used as the blasting medium.

Complicated molds are cleaned throughout. Tolerances are held to .0001" —substantially increasing mold life.

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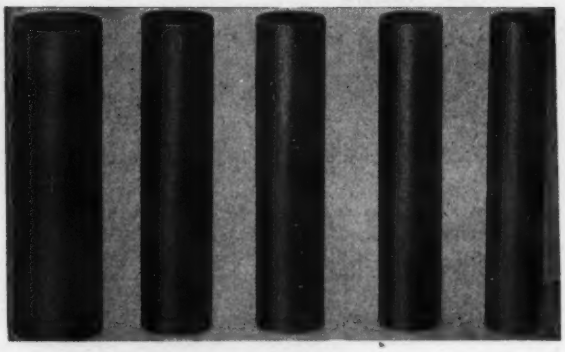
GUNITE



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Gunite can be machined with relative ease, yet has a high density that will take a brilliant polish. Round Bar Stock is available in 18 sizes from ¾" to 5" diameter, all bars 14" long. There is a suitable Gunite alloy for many types of glass-making castings such as Plungers, Ring Sticks, Neck Rings, Guide Rings, Moulds, Blanks, Bottom Plates, etc.

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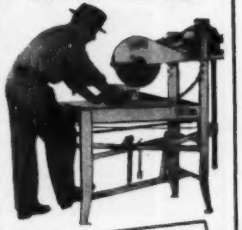
New Slant on MASONRY CUTTING

MAKE Any CUT IN SECONDS WITH NEW 1949 Clipper MASONRY SAWS

CUT WET—CUT DRY



You can slice through the hardest masonry materials quickly, easily, and economically with new portable Clipper Masonry Saws. There's a secret behind this smooth, fast cutting Clipper action—it's the automatic Pressure Equalizer Spring. Clippers are built to withstand the roughest treatment on any job yet will consistently make straight and intricate cuts in seconds. Clipper, the only masonry saw with the Pressure Equalizer Spring, combines the Multiple Cutting Action with the new "Adjust-A-Cut" control to make possible the fastest cuts at the lowest cost.

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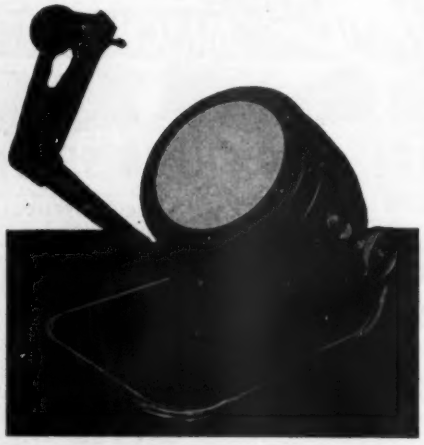

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